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HEARING

BEFORE THE

SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY U.S. HOUSE OF REPRESENTATIVES

NINETY-NINTH CONGRESS

SECOND SESSION

APRIL 9, 1986

[No. 92]

VOLUME I

Printed for the use of the
Committee on Science and Technology

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U.S. GOVERNMENT PRINTING OFFICE

60-960 O WASHINGTON : 1986

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1987 NASA AUTHORIZATION

WEDNESDAY, APRIL 9, 1986

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON TRANSPORTATION,
AVIATION AND MATERIALS,
Washington, DC.

The subcommittee met, pursuant to notice, at 9:31 a.m., in room 2325, Rayburn House Office Building, Hon. George E. Brown, Jr. (chairman of the subcommittee) presiding.

Mr. BROWN. The subcommittee will come to order.

I have a short opening statement which I will read.

Today, the subcommittee will consider NASA's fiscal year 1987 budget request for aeronautics, the first "A" in NASA.

This year, in addition to the ongoing aeronautical program, NASA is requesting $45 million as its contribution to a new national program headed by the Defense Department. The purpose of this program is to mature the technology and prove the feasibility of an aerospace plane capable of extended hypersonic cruise in the upper atmosphere or single stage to orbit operation. Both Dr. Colladay from NASA and Dr. Duncan, the Director of the Defense Advanced Research Projects Agency, will review various aspects of this program.

Of course, we do have a severe budget deficit this year, and we must deal with it by holding or, in some cases, reducing expenses. So, we will want to look closely at this and all other programs to be sure the costs are fully justified.

In aggregate, I feel the NASA budget for aeronautics is a healthy one, considering the times we are in. Nevertheless, I want to assure that the limited resources available are applied to the highest priority research areas.

For this reason, we will also hear from two advisory groups.

The first, known as the Congressional Aeronautical Advisory Committee, was established by my predecessor as chairman of this subcommittee and continued by me for the purpose of reviewing in detail the aeronautics budget request. Composed of experts from industry, academia, and the military, this group spent many dedicated hours since last fall examining virtually all of NASA's research projects and considering a number of larger issues as well. We will hear the results of its work later in the hearing.

The second advisory group which also reviewed the fiscal year 1987 program is from the American Institute of Aeronautics and Astronautics which represents many of the professional engineers and scientists in these fields.

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That concludes my opening statement.

Our ranking minority member who is unfortunately not here also has a statement, I understand, and, without objection, that will be included in the record at this point.

[The prepared opening statement of Mr. Lewis follows:]

OPENING STATEMENT FOR
HON. TOM LEWIS (R-FL)
SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS
HEARING ON FY 1987 NASA AUTHORIZATION (AERONAUTICS)

THANK YOU

MR. CHAIRMAN, I'M SURE WE ARE ALL GROWING WEARY OF HEARING ABOUT GRAMM RUDMAN AND BUDGET CONSTRAINTS. I'M SURE WE WOULD ALL LIKE TO SIT UP HERE AND ANNOUNCE THAT THE PROBLEM HAS BEEN SOLVED AND WE ARE NOW PROJECTING A HUGE SURPLUS. WE WOULD LIKE TO -- BUT THE TRUTH IS WE'RE STILL MORTGAGING OUR CHILDREN'S FUTURE BY SPENDING MONEY WE DON'T HAVE.

THIS HAS TO TURN AROUND -- AND PERHAPS THE GRAMM-RUDMAN PROCESS WILL FORCE US TO START MAKING SOME OF THE HARD CHOICES THAT ARE NEEDED. BUT, WHEN WE DO, I HOPE WE CAN KEEP IN MIND THAT RESEARCH CONTINUES TO BE ONE OF THE BIGGEST BARGAINS WE CAN GET FOR OUR TAX DOLLARS.

RESEARCH IS AN INVESTMENT IN THE FUTURE, AND CERTAINLY THE DIVIDENDS AMERICANS HAVE RECEIVED FROM AERONAUTICS RESEARCH IN THE PAST HAS CERTAINLY JUSTIFIED THAT INVESTMENT. SO IN OUR DESIRE TO SPARE OUR CHILDREN AND GRANDCHILDREN THE BURDEN OF A HUGE DEBT, WE SHOULD NOT BE SO SHORT-SIGHTED AS TO CHEAT THEM OUT OF THE BENEFITS THAT SCIENCE AND TECHNOLOGY CAN OFFER.

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I'M PLEASED TO SEE FROM THE BUDGET THAT HAS BEEN SUBMITTED THAT THE ADMINISTRATION RECOGNIZES THE IMPORTANCE OF AERONAUTICS RESEARCH. I'M PARTICULARLY PLEASED TO SEE THE NEW EMPHASIS ON HIGH-SPEED AERONAUTICS. THIS HAS BEEN ON THE BACK BURNER FOR TOO LONG. IF NASA IS TO BE THE LEADER IN DEVELOPING THE ADVANCED TECHNOLOGY FOR TOMORROW'S AIRCRAFT, IT MUST HAVE THE VISION TO SEE BEYOND THE DEMANDS OF TODAY'S AVIATION CONSUMER.

I'M DISTURBED BY RECENT ATTEMPTS TO CHARACTERIZE THE AEROSPACE PLANE AS A TRANSPORTATION SYSTEM FOR THE RICH. THIS RESEARCH AIRCRAFT WILL PROVIDE THE TECHNOLOGY NEEDED FOR A WIDE RANGE OF FUTURE APPLICATIONS AND EXEMPLIFIES THE KIND OF VISION THAT I BELIEVE IS NEEDED; IT DESERVES OUR SUPPORT.

THANK YOU MR. CHAIRMAN.

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Mr. BROWN. I will now recognize Mr. Packard and ask him if he has any statement he would like to make at this time.

Mr. PACKARD. No, Mr. Chairman. I appreciate your calling the hearing, and I have no preliminary opening statement. I think that you have agreed to have Mr. Lewis' statement in the record.

Mr. BROWN. Mr. Lewis' statement will be in the record.

Mr. PACKARD. And that is certainly adequate for me. Thank you very much.

Mr. BROWN. Our first witness, then, will be Dr. Raymond S. Colladay who is the Associate Administrator, Office of Aeronautics and Space Technology for NASA, and we will append his distinguished biography in the record at this point and recognize him for his testimony.

Dr. Colladay, we are pleased to have you here this morning.

STATEMENT OF DR. RAYMOND S. COLLADAY, ASSOCIATE ADMINISTRATOR, OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY, NASA

Dr. COLLADAY. Thank you, Mr. Chairman.

I am pleased to be here to present NASA's fiscal year 1987 aeronautics and transatmospheric R&T budget request. I have a written statement that, with your permission, I would like to submit for the record and just summarize.

Mr. BROWN. Without objection, it will appear in full at this point in the record.

Dr. COLLADAY. Thank you.

I am convinced that if we stay on our present course, we will see advances in aviation unprecedented in our lifetime and enter the 21st century assured of U.S. leadership in air and space flight. That is a conviction that maybe not everyone or maybe not even most of the people in this room would share unchallenged, but I have been looking into the opportunity we seem to be facing to see if it really is all that unusual, and I think it is.

What is it in this business that seems to cause progress to occur in steps or jumps with a flurry of new developments interspersed with plateaus that seem to be level where progress appears to occur in more evolutionary than revolutionary steps? History is a good teacher, and I have gone back over the 70 years that NASA and NACA have been in this business to get some insights.

Engineering advances, the practical application of technology, do occur in jumps, but the progress in the research laboratories, the small incremental accumulation of knowledge, is steady. I spent 15 years early in my career in the research laboratory, and from my perspective then, breakthroughs were occurring all the time, maybe small, but they proceeded with a pace that, for the researcher involved, was indeed steady.

The engineering advances tend to occur only when we reach a critical mass of accumulated knowledge and technological achievements through years of research. But something else also seems to happen, maybe even more significant, and that is that technology is often applied to a system in ways for which it was not originally envisioned. When that happens, the pieces fall into place with such

elegant simplicity that one wonders in hindsight why it wasn't obvious.

That says two things to me. First, we shouldn't be so sure we know the end application of our research results. Second, we should have the patience to invest in long-term R&T. It is essential to continued progress.

That is what this NASA program is all about. Congress has always been a strong supporter, even at times when its very existence was threatened. Now, we are on the threshold of one of those big jumps forward, maybe the biggest ever. For the sake of our economic and defense security, I hope we won't let present budget pressures turn near-term savings into long-term losses.

I need your continued support for the program and the budget I am requesting. I make that request fully aware of the difficult fiscal environment we are in today. Priorities have to be set and tough choices made. We have done that. In an overall agency budget for NASA that has declined in real dollars, aeronautics and the transatmospheric R&T portion, which is NASA's part of the National Aerospace Plane Program, have been given priority.

As summarized in figure 1, we are requesting $376 million for aeronautics R&T, up from the $337 million post Gramm-Rudman-Hollings reduced level for fiscal year 1986.

In addition, we are requesting a new budget line item for transatmospheric R&T which, as I mentioned, is the NASA portion of the joint NASA-DOD National Aerospace Plane Program.

Because space technology also provides a foundation from which the transatmospheric R&T has grown and is built on, it is also included in the figure.

I would like to touch on a few areas in the fiscal year 1987 budget which I feel deserve special mention for their potential to affect future civil and military aircraft progress.

Numerical Aerodynamic Simulation [NAS] is emerging as a powerful tool as essential to aircraft development as wind tunnel simulation has been before it. Certainly, it won't replace wind tunnels, but it will forever change the way we use them.

Our numerical simulation capability will go into full service on a national scale in July of this year. Shown here is the Cray II high speed computer, the first high speed processor in this system (fig. 2). It is the computing engine for the entire NAS system. Don't let the size fool you. It is the world's most powerful computer and has more memory than all the Cray machines sold to date.

Using this machine as we are now in the benchmark tests, it is being applied for both internal propulsion flow and external flow around complex aircraft shapes. This flow field in rotating turbomachinery was made on one of the new NAS work stations. The blade row is rotating relative to the fixed set of upstream vanes, and there is no discontinuity in the flow field, even though it passes from a fixed to a rotating grid (fig. 3).

On external flow applications, we are able to compute the flow around real aircraft configurations like the F-16 shown in figure 4. The grid defines the computational points in the Navier Stokes solution. We are using the F-16 as a referee benchmark case for code verification and computer acceptance testing. It happens to be par-

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ticularly useful because of the rich data base that exists on that airplane both in wind tunnel data and flight data.

For the purpose of comparing codes with different research groups across the country in industry, our NASA laboratories and universities, we use that referee benchmark data base to referee the codes. We are doing that in a number of other applications as well as the F-16, the most recent being a documentation of the complex rotor flow on a helicopter in rotor integration with the fuselage.

We are also applying computational fluid dynamics methods to modeling severe storm wind shear conditions to help simulate and better understand the critical aviation safety problems associated with this type of atmospheric behavior. Figure 5 here illustrates one cell in a microburst pattern, shown in computation form and in cartoon form around the microburst at ground effect area near the surface.

The model results that we get from this computational effort are then fed into our simulators to give pilots a first hand feel for aircraft handling characteristics under such conditions.

Numerical simulation with large parallel processing computers is also opening the door to breakthroughs in computational structural analysis. In figure 6 you can begin to see the extent of the nodes that must be identified in breaking up a typical airframe. This is the X-29 forward swept wing.

While NASTRAN has been the design tool of almost universal acceptance, it was developed back in the late sixties. Granted, it has been improved over the years, but progress in algorithms and computers now make a new generation of computational structures code extremely attractive, and we are moving in that direction.

Research in advanced composites is taking a whole new turn as we develop the next generation damage tolerant materials. I have asked the National Academy of Sciences this past year to pull together, under the direction of the Aeronautics and Space Engineering Board, an indepth study on what the technical barriers are to greater use of composites in aircraft and where NASA should focus its research efforts in the future. With the program that we are now putting in place, I feel it will finally be able to fully exploit the unique properties of composites, using approaches that deal with 3-D weaving methods of fabrication that can increase damage tolerance and strength.

Supermaneuverability in advanced aircraft adds a new dimension to expanding the flight envelope. Our research in adapting propulsive flight controls shows incredibly stable performance can be achieved at high angles of attack as shown in this free flight wind tunnel test at Langley of an F-18 model (fig. 7). It is flying under control with full maneuvering capabilities at an 80° nose up angle relative to the approaching airstream. That was unprecedented just a short while ago. In the standard configuration of the airplane, it is unstable at angles of attack much, much less than this.

In rotorcraft research, we are expanding our efforts in fiscal year 1987 to tackle the twin problems of noise and vibration. This is a tightly integrated program with the colocated Army labs at Ames, Langley, and Lewis and a cooperative effort with the rotorcraft in-

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dustry as it is administered through the American Helicopter Society.

Finally, nowhere is our move to emphasize revolutionary technology more apparent than in the National Aerospace Plane Program. This joint DOD-NASA program to demonstrate the feasibility of hypersonic flight in the atmosphere and on into space with an experimental vehicle, now designated the X-31, is another in a long series of distinguished experimental aircraft programs designed to expand the flight envelope.

Part airplane, part spacecraft, the aerospace plane is shown here (fig. 8) as a picture of a model of one of the experimental configurations we are analyzing, and there are a number that will be explored as we pursue the innovative concepts and different configurations in the early part of the program.

The plane will take off horizontally from a conventional runway, climb through the atmosphere on the thrust of powerful scramjet engines, scooping up huge quantities of air for oxygen that doesn't have to be carried on board. The rocket assist for orbit insertion and deorbit would, of course, require some oxygen in the final stages of flight and return from orbit.

The applications of this technology offer the possibility of a whole family of operational vehicles. Hypersonic transports that would stay in the atmosphere and cruise at, say, 4 times the speed of sound or even faster, maybe as high as 10 to 12; high speed military strategic vehicles; and space launch vehicles as a next generation to the space shuttle able to greatly reduce the cost of delivering payloads to orbit.

This program itself is a perfect example of what I was talking about earlier of how progress is built on accumulated advances over years of research all coming together like pieces of a puzzle. As the program chart shows in figure 9, the technical foundation was laid through years of research over the last decade and even longer, much of it in the NASA aeronautics and space R&T budgets shown in the top line in this program chart. That was followed by focusing of the applicable technology in phase 1 that set the stage for the accelerated technology development in phase 2 that we are pursuing now. That will lead to a critical decision on the X vehicle go-ahead in the late 1980's and a flight, if the decision is indeed to go forward, of the X-31 in the early to mid nineties.

Once the technology is validated, development of operational vehicles could then take place. Although they may be considerably different than the experimental vehicle, they would all have the same pedigree in technology from the program that we are embarking on now.

The list of key technologies is for sure long, but the head of the list has to be the engine system and the heart of the concept of the propulsion system is the scramjet operation, producing enough positive thrust over drag to propel the aircraft and accelerate it through the atmosphere. We pioneered its development at our Langley test center (fig. 10) in just the scramjet mode at subscale. Over 1,100 separate test runs to verify engine performance have been conducted over the last several years.

Second on the list of enabling technologies for this promising new vehicle is the ability to integrate that propulsion system with

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the airframe. In fact, the integration of the propulsion and the airframe are unprecedented in any vehicle we have ever developed.

Because of the limitations in ground based facilities and the importance of integration of the total vehicle, flight testing of an X vehicle is a must. We have had a series dating over 20 years of experimental vehicles just for the purpose of expanding the flight envelope and integrating the technologies into an overall feasibility test program. That is what the experimental vehicle in this program will deliver. Just as the X-15 (fig. 11) blazed new trails on the frontiers of flight and the X-24B lifting body in figure 12, both of these combined to provide the data base and the confidence to proceed with the shuttle system as well as other spinoff technologies to systems that followed.

As we look into the future, with all of these expected accomplishments, I wouldn't want to lose sight of the fact that the program at present is achieving the objectives, and remarkable objectives indeed, that we set for ourselves some time back and that this subcommittee has set with us.

The best way to illustrate that is with two examples that alone could write a new chapter in commercial aviation for short and medium range transports and contribute substantially to the United States competitive edge. These two examples are tilt rotor with the XV-15 and the advanced turboprop which will be in flight test well before next year at this time.

NASA developed and demonstrated the tilt rotor concept shown in figure 13, combining the advantages of the helicopter and a turboprop airplane. We did it jointly with the Army. Now, as has been typical of many aircraft developments in our history, the military V-22 will offer the first operational experience with the vehicle, but I fully expect that it will be soon followed with a commercial vehicle which will link downtown to downtown intercity pairs and local airports to major airport hubs.

The advanced high speed turboprop will very likely lead to a whole new generation of medium-range transports for the 1990's (fig. 14). The advanced turboprop program was started by NASA in the early 1970's and is progressing on plan for a flight test within a year. Much of the credit for bringing the flight program into its present state rests with this subcommittee.

Stepping back and taking stock of the progress we are making in aeronautics in the NASA program and the successful partnership we have with other Government agencies, the industry, and universities, I am generally satisfied that we are on track and on the track that I have laid out in our long-range plan.

The national R&D goals for aeronautics provide a framework for implementing a bold new course as they represent a consensus—and this fact is pretty remarkable—a consensus among Government, industry, and academia on what needs to be done for the next decade.

With constraints on the budget, I realize that we can't pursue all the attractive opportunities nor can we be satisfied with seeking only small incremental gains. Tough programmatic decisions will continue to lead to a curtailment of good research in favor of higher payoff areas that are focused on those emerging technologies that offer an order of magnitude improvement in perform-

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ance, what I call the 10 dB bell ringers that we are trying to focus on in the program.

The President's fiscal year 1987 budget request for aeronautics and transatmospheric R&T represents a positive step, and I urge your support for that budget.

Thank you, Mr. Chairman. That concludes my prepared remarks. I would be happy to try to answer any questions you have at this time. I have with me my budget director and my aeronautics deputy to assist me in addressing any of those questions that I need help on.

Mr. BROWN. Thank you very much, Dr. Colladay.

It would appear to us that in the aeronautics program, we have a fortunate situation where we have strong administrative support for the program coupled with congressional enthusiasm for the program which bodes relatively well, it would seem to me, for moving ahead vigorously in this area.

Can you illuminate for me whether or not there have been any major differences between NASA, the OMB, the Executive Office with regard to the overall program? Are there any large-scale missed opportunities or differences that might have developed with regard to the timing of the program or other things of that sort?

Dr. COLLADAY. I don't believe so, Mr. Chairman. I think the fiscal year 1987 budget request represents a consensus that has converged to closer agreement between the agency and the OMB in the budget decision process than we have had at any time over the last 4 or 5 years. I think there is a strong support for the aeronautics program, certainly a very strong support in the administration for the National Aerospace Plane Program which is a key part of our request this year, and there was very little disagreement between our plan that we went forward with in this budget cycle and what we came out of that process with. There are always some small differences, of course.

Mr. BROWN. What are the rough parameters with regard to, say, the aerospace plane? To what degree could more or less money affect the timeframe that you outlined in the chart there?

Dr. COLLADAY. I don't think more money could appreciably accelerate the effort. It could certainly reduce risk in a number of key technology areas if we had more money in the front end technology development, but I think all of us, all the participants in the program, are reasonably comfortable with the scope and the budget level, and we feel that it isn't something that the schedule is going to yield to a big infusion of more money.

We are paced by the challenge of the technologies. In many of those cases, throwing more money at it, to put it pejoratively, isn't going to get us there any faster. It is an extremely aggressive program and the budget is tight, but I think it is one that we find acceptable.

Mr. BROWN. As you have indicated, there are a number of important technologies that are required in order to bring this program to successful fruition. You have outlined some of them and indicated the progress we have made in them.

Are there any particular technological areas where we are, we will say, behind the curve or where extra effort is needed to bring

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them together at the proper time when we are ready to, say, move into flight testing or something like that?

Dr. COLLADAY. Well, one area that comes to mind that is going to need a great deal of accelerated effort is computational fluid dynamics. There hasn't been an airplane design that we have ever embarked on that is going to rest more heavily on our ability to predict the flow field around the aircraft configuration than is the case in this vehicle.

The reacting boundary layers, the high speed flow on the very edges of continuum of the atmosphere are going to put demands on computational fluid dynamics that are unprecedented. But I think we are pretty well poised to address that.

We have the numerical aerodynamic simulation effort coming on line just at the right time. We are going to put a considerable amount of effort into advancing the codes and doing good experimental verification of those codes over these next 3 years, getting ready for the X vehicle design. NASA, as you know, has invested heavily in computational fluid dynamics in our aeronautics program over the last 4 or 5 years.

So, I think that is all coming together, but I do have certain reservations on the need for accelerating it.

Mr. BROWN. Describe to me in lay terms what the weaknesses are. Does the new Cray machine give you all of the computational power requirements to do what you need to do, or would it be further aided by a new generation machine? The codes that you refer to, how difficult is it to develop these codes and how are we fixed for securing this development and utilizing these codes?

I suppose these codes are what is required to make the Cray machine give you the answers that you want. Do I understand this correctly?

Dr. COLLADAY. Well, the codes are under development, and the Cray machine gives us the kind of memory capability to be able to solve those codes in an efficient way, efficient still taking hours to run on the fastest machine in the world.

I think as we go into this program, we are going to be upgrading the system with a next generation high speed processor which I fully expect to be available in the next 2 or 3 years. A very important aspect of that code development, though, is the verification experiments that need to be done, the detailed experiments at high speed hypersonic flow to make sure that we have them properly calibrated.

I don't think there are any show-stoppers here. I just think it is going to be a major effort that is going to require focusing our attention on.

Mr. BROWN. Well, verifying requires experiments conducted in advanced wind tunnels, I presume.

Dr. COLLADAY. That is correct.

Mr. BROWN. And we therefore have to have available the kind of facilities that will allow us to get this information. Are these kinds of developments adequately provided for in the program that you have outlined for us here?

Dr. COLLADAY. Yes, we believe so. We have in the fiscal year 1987 budget request on construction of facilities a second element of the 8-foot high temperature structures tunnel that we think will be a

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critical element of the facility base for the program. We are reactivating the 3.5-foot hypersonic wind tunnel at Ames. We have a number of arc jet facilities that will be used for small-scale code verification.

In fact, when I look across our whole inventory of aeronautical facilities in the agency as well as those of the Air Force and the industry, as a country, we are going to be employing a major part of our facility assets for this program. But I think we are aware of what the facility needs are and are taking steps, each of us, to make sure that they are available in a timely way.

Mr. BROWN. Looking at some of the other technologies, do you feel similar confidence that we are going to be able to have available the materials technology required for the extremely high temperature operations, the kind of technology required for cooling using hydrogen, I presume, and the design of the structures that will enable us to do that? Are all these at a similar level so that they are proceeding in tandem to a point where we can put them all together?

Dr. COLLADAY. I believe so They are. That is really why we are doing the program. It is a technology program. It is a research program, getting all the answers to all those questions over the next 3 years and then putting it together in an experimental vehicle, all done before we make a decision on whether to develop an operational vehicle.

I don't see any show-stoppers. I think it is a well integrated program with all of the critical paths, and there certainly isn't just one of them, all coming together at the proper pace.

Mr. BROWN. Well, I know you are presenting an optimistic scenario here, but it would help if we knew where the failure points might be and what to look forward to in case there is a need for extra effort or something of that sort. Of course, it is nice to know that you have everything under control.

Dr. COLLADAY. Well, I am optimistic, but I am also sufficiently sobered by the challenge that I know it is going to be tough. We are going to run into problems along the way, but we are just starting the program, and we are going to learn what those are over the next 3 years. I am sure there are going to be surprises along the way. I just can't, at this stage of the program, tell you what they are that we haven't covered as we start down that path.

Mr. BROWN. I am cogitating about what to do about those bells. I think we better go over and vote.

Mr. PACKARD. I think my questions, Mr. Chairman, would take longer than what we would have available, so if it would be possible to vote before we conclude——

Mr. BROWN. OK. Can you remain with us after a brief recess of 10 minutes or so?

Dr. COLLADAY. Certainly.

Mr. BROWN. All right. The committee will take a short recess to vote, and we will be back as quickly as possible.

[Recess.]

Mr. BROWN. Dr. Colladay, with regard to the aerospace plane which is, because of its excitement and so forth, going to be the center of a lot of attention both pro and con, I would like to have you clarify the management arrangements as between NASA and

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the DOD with regard to the development of the program just to put something on the record here.

Dr. COLLADAY. Well, Mr. Brown, I wish I could be more specific and tell you that all the pieces have been put in place. We aren't there yet. We do have a general understanding of how that management structure will unfold. The Department of Defense role with overall program responsibility resting with the Air Force and the lead in phase 2 resting with DARPA is agreed to, and NASA's role in the technology development is in place.

The way the whole structure functions, from the Secretary of Defense and the Administrator of NASA down through the joint program office at Wright Patterson, the details of that have not been finally reached and signed out in the memorandum of understanding that needs to be put in place for the program.

Mr. BROWN. You do not yet have a detailed memorandum of understanding or you are working on one?

Dr. COLLADAY. That is correct. We are working on one.

Mr. BROWN. Do you have a timetable for when you expect to achieve agreement on that?

Dr. COLLADAY. Well, I fully expect it will be within a week or two.

Mr. BROWN. But the overall responsibility will rest with the DOD acting through the Air Force.

Dr. COLLADAY. Yes, sir.

Mr. BROWN. NASA's role will be presumably a continuation of the activities in technology development which it is currently doing the work on through the labs, I presume.

Dr. COLLADAY. Yes, sir, and my objective in reaching an agreement on the organization is that we make sure that that laboratory effort on the technology development is an integral part of the mainstream of the program and not some separate off to the side parallel activity backstopping the rest of it.

Mr. BROWN. You don't want DOD to contract out the work that you are already doing.

Dr. COLLADAY. Well, we want to be part of it. It is a joint program, and it needs to be organized, the management structure needs to be organized as a joint program.

Mr. BROWN. Well, I am sure you know this committee would be very solicitous of NASA's role, and I hope you will be frank with us in discussing any problems you might have in reaching a satisfactory agreement with regard to the overall management.

Dr. COLLADAY. I will, sir. Give me a couple of weeks and I will be able to report out.

Mr. BROWN. Mr. Packard, would you like to continue with questions?

Mr. PACKARD. Thank you, Mr. Chairman.

I appreciate, Dr. Colladay, your being here along with the other witnesses.

As you well know, the Congressional Aeronautics Advisory Committee is there to assist in making budgetary decisions and making recommendations. NASA has expressed concern that in their role, and I would like to know how you deal with their advice and how you deal with their recommendations.

Your program appears to reflect considerable change based upon their recommendations, that is, reductions in emphasis on CFD and increase in rotorcraft vibration research, reductions in AWT. Did you find their recommendations valuable in realigning your budget proposal?

Dr. COLLADAY. Well, Mr. Packard, we deal with the industry a lot. We have a number of interactions through the year in a very complicated budget decision process that deals with the industry and academia and our other Government agency partners in the aeronautics program. We weigh all of that advice.

Now, the Congressional Aeronautics Advisory Committee is not our advisory committee; it is yours. So, we don't take explicit action based on that advice. It happens that the advice or the output or findings and recommendations of your advisory committee, not surprisingly, overlapped many of our own. Many of those things that you mentioned we were planning to do anyway.

I would point out, though, on one of those items that the computational fluid dynamics effort, as a whole, hasn't been reduced. When you include both the analytical CFD and the experimental verification which, to me, is all the same research effort, it is an increase over last year.

We take advice that we get from all of our industry associates and advisers into a perspective of time. At any one time, at any snapshot in time, you can get not only conflicting advice among the members of an advisory committee but between members or employees of the same company. We try to look at the input that we get from all of our advisory committees over a longer period of time with a lot of checks and balances in the system.

The changes that we made to the program, I would say, were the result of the accumulation of all of that input, testing it back with the industry, many times the CEO's and presidents of companies, to make sure that we did have the view reflected from the industry as a whole. That was what motivated the changes more than I could attribute to that specific set of recommendations of your advisory committee.

Mr. PACKARD. You referred to your having other advisory committees of your own that you rely on and use.

Dr. COLLADAY. Yes, sir.

Mr. PACKARD. What interaction and how are they brought into the picture and generally what does the aeronautics community do in helping you to formulate your programs and budgets?

Dr. COLLADAY. It is extensive, Mr. Packard. It covers a full budget cycle of a year and, many times, for some of these strategic issues, in setting long-term direction, it happens over a period of time even exceeding a year.

We deal with the overall strategic direction of the program and those associated issues with the Aeronautics and Space Engineering Board of the National Academy of Sciences. These are high level management people from the aerospace industry and university community.

We deal on a policy level with the CEO's and presidents of aerospace companies in the Office of Science and Technology Policy Aeronautical Review Committee at the highest level.

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At another plane, there is a program development level on our Aeronautics Advisory Committee that has some 80 members from industry and academia. They get into the details of the program. We meet with them four or five times a year, and they have both an oversight function, a check and balance of our program, as well as helping in program development.

Then we have peer reviews where the industry comes in and looks in a very detailed way at the implementation of the program at the center.

Then, in the fall of the cycle where we have completed 1 fiscal year, we invite those advisers in to look at "how goes it." How did we do compared to what we said we were going to do at the beginning of the year and where are the problems? Are the accomplishments of a caliber that we think is appropriate and, if not, what areas should be cut out of the program and what should we build up?

Mr. PACKARD. Do you generally follow the advice of your advisory committees or peer review groups?

Dr. COLLADAY. Not always. But we always answer very explicitly all the recommendations that they make, and we weigh that advice and all the competing priorities. On the whole, I would say we do, to a large extent, follow and implement their recommendations. But at any given time, there is disagreement among elements of the same industry and the same vehicle area or between segments of the industry where there is a check and balance, a pull and a tug, on the program resources. There is always much more to do than we have resources to fund in promising areas, so we can't do everything. We try to put that all into balance.

Then, where there are major strategic changes in the program, we don't make those quickly. We don't respond to one snapshot in time. We will test it over time, because we find that advice very often changes.

One year, there can be a decidedly negative reaction to a part of the program only to turn around 12 months later and have an area be the greatest thing since sliced bread. We can't keep jerking the program around that way. So, on major strategic changes, we do take some time to put it all in perspective and test it over time to see if they really are the right things to do.

Mr. PACKARD. The Senate Budget Committee has proposed a budget freeze. How would that affect NASA's R&T programs, particularly the Aerospace Plane Program but also the other aeronautics programs as they have been outlined?

Dr. COLLADAY. Well, Mr. Packard, I think it would be devastating. It represents about $100 million if we are frozen at the 1986 level. You saw the increase in aeronautics and transatmospheric R&T that NASA as an agency requested, and that was within an overall budget where we did make the trades and set those priorities.

To freeze that then at the 1986 level, we would not experience or enjoy the growth that we had targeted for this year for some very important things in the aeronautics program. It would be to suboptimize the program.

The agency's budget did not increase in real terms, and yet aeronautics shows a fairly substantial increase, and that was deliber-

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ate. That was recognizing the tremendous payoff that we are on the verge of cashing in on.

I would find to be frozen at the 1986 level with that kind of reduction would have a major impact on all these major programs, particularly the big flight programs that we have planned.

Mr. PACKARD. What are the specific requirements that are driving the NASP Program? Would you comment on the likely civil applications that might evolve from that program? For instance, to what extent would the program fulfill our future space transportation system requirements, and how would such a hypersonic vehicle fit into the future world commercial aviation market?

Dr. COLLADAY. I think the civil applications from this program are very real and ought to be kept in appropriate balance as we look at where the payoffs are going to be and balanced consistent with military applications.

Our plan, the way we have constructed the program as a technology program, is that we provide a test bed to spin off a number of technologies to vehicle systems of the future and enable a family of operational vehicles that cover both civil and military applications.

I think there is promise for a hypersonic transport. I don't believe it will be the first application of the technology that comes out of the Aerospace Plane Program, but it very definitely, in my opinion, is in our future. If you go back to the vision of the early 1900's that people had for commercial aviation, nobody envisioned what we enjoy as a natural occurrence today, and I think we are about where we were in 1900 looking at the application of this hypersonic technology for commercial application.

Now, as a launch vehicle, what we are trying to do is create a level playing field for the decision on the next generation to the shuttle and look at the air breathing option with all the promise that it holds as a way of reducing payload delivery to orbit, cost of a payload delivery to orbit, and let it compete with rocket systems.

I would point out that much of the technology that is developed in advanced materials and hot structures and computational fluid dynamics and the like are also going to be applicable to transportation systems that are rocket powered.

But those of us associated with the Aerospace Plane really believe that there is a pony in here that can substantially reduce the cost of delivering a payload to orbit, and that is so important to our future in space and the routine commercialization of space that it is worth going after. I think somewhere down there we are going to see an air breathing single-stage-to-orbit vehicle.

Mr. PACKARD. In the management structure envisioned with DARPA being the program manager, what control will NASA have over cost overruns and what responsibilities will they incur in regard to any cost overruns?

Dr. COLLADAY. Well, in organizing the program as a true joint program between DOD and NASA, we will be a part of those decisions that are going to come up as hard points in the program when we reach situations where we are facing an overrun. As an integral partner of the program, we are going to have to share in meeting those overruns if they occur.

We are approaching it as a joint effort where NASA and DOD are sharing the responsibility.

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Mr. PACKARD. I think a perception is that NASA is not aggressively pursuing the critical technology in regard to the supersonic cruise. Would you make a comment on that?

Dr. COLLADAY. I think that is a fair criticism, because I don't know what we should do at this point. I think it would be wrong to just charge off with a major technology effort right now before we have looked in an in-depth way at the critical technologies and what the economic payoff is for supersonic cruise vehicle.

We are going to do that this year. We plan to go out involving the industry in definitive studies for high speed supersonic cruise to look specifically at civil applications of technology. We know what the three big technologies are. They are high temperature, light weight composite materials, supersonic laminar flow, and efficient variable cycle engine systems. They are all critical to a viable supersonic cruise transport aircraft.

Whether the environmental issues are properly addressed in those technologies, what the niche is in a potential market for such an aircraft, what the pace of those technologies ought to be, and what our investment strategy should be I don't know yet. So, we do have a relatively low funded effort in supersonic cruise building up because of the studies I referred to, but not charging ahead with a major acceleration in those three technologies until we have done our homework.

Mr. PACKARD. You mentioned in your testimony the national aeronautic R&D goal as providing a framework for your planning and programs. How has NASA as well as the entire aeronautic community responded to your national goals?

Dr. COLLADAY. I think you are seeing the first fruitful results of the consensus that has been built around those national R&D goals. Certainly, the transatmospheric goal was key in that set of three vehicle goals. You see almost an unprecedented Government cooperation in launching the Aerospace Plane Program, not just Government, but industry as well.

So, I think there is a strong response to those goals. To the extent that they do represent a consensus between the Government and industry on who should do what and where we ought to make our investments, I think you also see that reflected in our subsonic transport program.

I think that the trend of opinion anyway—maybe I can't call it a full consensus yet—but certainly the trend is that the subsonic transport area has reached a point where the industry can carry it into a new product with the possible exception of hybrid laminar flow, and that we are not convinced what the right thing to do is. Supersonic cruise, as I mentioned, is the third goal, and is somewhat uncertain yet.

But I think the reaction has been favorable in both the Government and the industry. You have seen the impact of those goals on our budget request, and I think it is working—those goals are providing the framework and the forcing function on our planning just as we said they would and hoped they would.

Mr. PACKARD. One last question, if I may, Mr. Chairman. What is NASA's rationale for eliminating most of the acoustical work in the ATP program?

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Dr. COLLADAY. We, under overall budget pressures in the aeronautics program, took a carefully measured response to what the industry build-up in the advanced turboprop area was and recognized that as the industry effort builds up, we ought to take a check on what our program is directed to do and make sure that the combined effort of NASA and the industry is a co rect response to bringing this technology forward to the marketplace.

The industry effort has accelerated faster than several years ago. We thought that it might. Fortunately, it has. That is very gratifying to us. It suggests that the program has been a success, but we are not there yet. We looked at what the most important thing to do was in the flight program, and that was scaling from the small scale wind tunnel test to the full scale type propellers in the testing that we are doing in the NASA program and felt that was the right Government funded program in the context of the total national effort that the industry was putting in, too.

We have scaled back or descoped the program somewhat, but we have retained what we think are the critical, essential features of that program.

Mr. PACKARD. It is true that industry is doing much more in that area, but their concentration is primarily on external noise levels, environmental concerns associated with it. I think you had also interest in pursuing cabin and internal noise. Apparently, industry is not picking that up.

Is that a concern to you?

Dr. COLLADAY. Well, it is going to have to be done, for sure, as the technology matures to a product development state. We are pursuing the structural borne noise technology in the core base program. The only part that has been scaled back is the high cost flight article part of that.

So, we are not walking away from it ignoring it. We are just scaling back the flight part of the research effort with the expectation that the industry will pick it up.

Mr. PACKARD. Thank you, Mr. Chairman. I apologize for taking so long, but I am asking questions that some of my colleagues who couldn't be here would like to have asked.

Mr. BROWN. We understand, Mr. Packard.

Mr. Mineta, we would like to recognize you if you have some questions of Dr. Colladay.

Mr. MINETA. Mr. Chairman, I really appreciate this opportunity to be here, not being a member of the subcommittee, but being a member of the full committee.

In another Committee on Transportation and Public Works, Dr. Colladay, I have the privilege of chairing the Aviation Subcommittee. One of the factors that I have been looking at is this whole issue of what is going to happen in the next 5 to 10 years in terms of the experience factor in the flight deck. I am afraid, in terms of commercial aviation, that in the next 5 to 10 years, the experience level in the cockpit is going to be going down quite a bit.

I had the opportunity a week ago Monday to spend a whole day up at Boeing to see what kinds of things they are doing in terms of the glass cockpit and recently, I had the occasion to visit the human factors division at Ames Research Laboratory which is

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right outside my district in California. I was very, very impressed by the work that they are doing there.

I visited Ames because of my work in the Aviation Subcommittee as well as the work of the full Committee on Science and Technology, because I constantly have pressed upon me the sad task of reviewing NTSB accident reports and can readily see how frequently human error is the ultimate cause of an accident. In fact, I believe about 80 percent of the ASRS's, the aviation safety reporting system incident reports that are reviewed at Ames as a matter of fact involve human error.

Human error is an increasing problem in aviation, a lot of problems there in terms of or attributable to lack of pilot experience, increased number of flights because of deregulation, a number of new airlines, the hub and spoke operation, lower jet fuel costs, the advent of new systems such as fly by wire, glass cockpit. These are all factors that make it even more imperative that work in human factors and commercial air transport be fully explored.

Clearly, NASA has the capability, the experience, and the integrity to do the job.

So, let me ask you about the $24 million that are earmarked for human factors research and technology. Of the funds that would be expended toward the subsonic transport/commuter general aviation category which is projected at $1.5 million in fiscal year 1987, what amounts would you estimate are being devoted toward improving the human performance with respect to designing and configuring the cockpit interior as opposed to human performance related to fatigue and performance, pilot judgment and training, crew experience and crew handling of new systems, because in going through your figures from NASA, it is difficult to get a sense of this from the numbers that have been provided us.

Dr. COLLADAY. Mr. Mineta, I may have to respond in detail for the record, but I can assure you that we take very seriously the role that Ames plays in particular. There is some human factors work at Langley, too, but the principal cornerstone of our in-house capability and national asset is the program we have out at Ames.

We have just gone fully operational over the last couple of years in the manned vehicle systems research facility that has two simulation cabs as well as an air traffic control station in that facility. It is not only a workhorse facility for our human factors research, but the industry and the airlines and the FAA use it as well. That gives us good cross talk and interaction among the principals involved in this very important issue and area.

We are looking at human factors in a broader context than we did just several years ago even in bringing in another key activity at Ames that we are building up in artificial intelligence and autonomous systems. That is a key companion effort to the human factors effort.

We are finding, particularly at Ames, when they are both lead activities there, that the two are playing very well together and synergistically, and we are looking at advanced automated cockpit systems to try to address the workload issue and provide the crew with the kind of information, not more and not less than what they need, to do the job and rely, where appropriate on artificial intelligence or expert systems.

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So, when you take that into account as well as the traditional human factors work on fatigue and circadian desynchronosis work that we have been doing related to fatigue and the workload measures that we are involved in and displays, the total is actually increasing.

Mr. MINETA. I am sorry. The total what is increasing?

Dr. COLLADAY. On autonomous systems and human factors combined as they work together.

We have no intention of cutting the effort in human factors as a total or specifically as it relates to transport operating systems. As far as the details of the budget, I would have to, with your permission, answer that for the record, because I don't have that with me.

Mr. MINETA. That would be fine, Dr. Colladay.

[Material to be supplied follows:]

NASA's aeronautical human factors research program has maintained a consistent and balanced level of effort between the vehicle classes. The following table shows the allocation of research funds by vehicle class.

SUMMARY OF FISCAL YEAR 1986 AND 1987 DIRECT AERONAUTICS R&D BUDGET APPLICABILITY BY AERONAUTICAL VEHICLE CLASS FOR AERONAUTICAL HUMAN FACTORS

[In millions of dollars]

	Fiscal year 1986	Fiscal year 1987
Transport	4.7	4.7
High performance	3.3	3.4
Rotocraft	6.5	6.8
Generic	7.5	9.1
Total	22.0	24.0

The amounts in the above table include the operation, upgrade and maintenance of research facilities, as well as support for in-house research, at all NASA Centers where aeronautical human factors research is performed. In consideration of the entire R&D activity, it is clear that NASA has maintained a strong research effort in the transport area, while modestly increasing its effort in rotorcraft research. About $1.1 million is being spent on research devoted to improving crew performance with respect to the design of the crew/cockpit interface.

Mr. MINETA. When I was up at Boeing, for instance, when you look at the 747-400 with the two-person crew anticipated on that plane, 885,000 pounds, 7,100 mile range, and I wonder about the human factors. Part of the operation of that plane with those kinds of long distances and really start wondering whether we are doing enough in the human factors area as we try to deal with this new generation aircraft coming along.

I guess, as you have indicated with AI and other things, I guess my question is, How can we ensure that pilots are prepared to interact with these new systems so that they are prepared for what they will find in the flight deck?

Let me go on then and ask about the proposed program levels for human factors R&T overall. In the budget, I see that rotorcraft would increase from $159,000 to $900,000, nearly a sixfold increase. I would like to ask what is driving such an increase given overall budget constraints.

Dr. COLLADAY. Probably the most severe challenge on pilot workload is faced in rotorcraft flight, nap of the Earth flying, particular-

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ly if you consider the move toward a single pilot operation. As a generic base of research that can force technology in the human factors area and, in addition, as a study on one of the most extensive environments that we can think of for pilot overload, that is it in rotorcraft.

We have a joint, as you know, effort with the Army who has a colocated Army lab at Ames. That reflects the planning that we are doing in the research effort to support the Army in the LHX technology development. But our reason for involvement is that it represents one of the most severe challenges in the human factors area on pilot workload.

Mr. MINETA. But when you look at rotorcraft growth, the use of rotorcraft as it relates to the general public, it is very little in comparison to what is happening as far as, let's say, jet transport or unducted fan or whatever other kind of technology that may be coming along as it relates to commercial air transport.

So why this large increase, recognizing single pilot operation, recognizing nap of the Earth flying procedures, et cetera? Why this large increase as it relates to rotorcraft and, from what I can understand, maybe a stationary or even a drop in terms of a commitment on commercial air transport side?

Dr. COLLADAY. Well, it is on percentage basis a large increase in the rotorcraft technology per se. Overall, it is not in absolute terms an unbalanced response to the kind of challenges we face in rotorcraft single pilot nap of the Earth flying.

We believe that the assets, the resource we have at Ames, is a national resource to be applied to national problems of both military and civil, just as our whole aeronautics program is. I don't believe that we are doing that at the expense of the other important area of transport human factors.

Mr. MINETA. When I look at the production figures on rotorcraft as compared to fixed wing, there is no comparison in terms that would justify this kind of increase.

Let me ask if the military is going to gain considerably from this research, are they contributing to this?

Dr. COLLADAY. Yes; they are.

Mr. MINETA. Or are they doing something separately also on their own?

Dr. COLLADAY. No. It is a joint effort and the Army is contributing substantial sums that are companion to our effort.

Mr. MINETA. Now, is this seen as sort of an income stream for NASA in order to relieve some of their own budget pressures on this?

Dr. COLLADAY. Well, it is an income stream, but it is for that particular program. The way the arrangement with the Army labs is structured and has been for the last 20 years it is difficult at times to tell the difference between a NASA researcher and an Army researcher. We plan the program together. We budget separately but in a coordinated way, and the work is all done using Ames facilities which occasionally are also provided or upgraded with Army funds.

It is a very close relationship we have between the Ames NASA operation, civil service operation, and the Army colocated laboratory.

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It is true, from just looking at the civil applications in transport versus rotorcraft, that the overwhelming application or incidence rate is in transport aircraft compared to rotorcraft, but there is a particular area of extreme importance to us in rotorcraft for Army applications that we are uniquely qualified to do through the resources we have at Ames. That is part and parcel of the agreement that we have with the Army.

Mr. MINETA. I recognize the importance of it, but as I look at the benefit to the public, it seems to me the public is much more dependent on general transport pilot human factors than they are on rotorcraft. Yet, there is this tremendous increase of $159,000 to $900,000 in terms of just that one area.

I recognize it is an important area, but we are getting squeezed all around. As I look at what is happening on the commercial side with reading these NTSB reports, seeing that experience factor drop, it bothers me to see what I might call the dislocation of resources being devoted to this.

You say the Army is contributing a portion of this $900,000? What percentage would you say of that $900,000 is coming from DOD sources?

Dr. COLLADAY. No, sir. What I meant when I said that was that the Army is budgeting in addition to the $900,000 that we are putting into that area for a total program funding level that I would have to get for the record. It is in addition to the $900,000. What you see is NASA's budget.

[The material referred to follows:]

Army Support for Human Factors Research at Ames Research Center

	Millions
Fiscal year 1986	1.309
Fiscal year 1987	1.658

This money is primarily in support of the Army-NASA Aircrew-Aircraft Integration (A3I) effort. This is a long term program for developing computer-aided human factors design tools. These tools will enable human engineering evaluation and design to make early and substantial contributions to improved rotorcraft systems designs.

Mr. MINETA. Is HAI or any other helicopter industry sources contributing to this research as well?

Dr. COLLADAY. The main effort of the industry cooperative effort is on noise and vibrations in rotorcraft. That is a separate function from the human factors research. So, I don't believe so.

Mr. MINETA. Can you give us an idea of the levels of funding that the private sector devotes to human factors and the type of issues that they focus on?

Dr. COLLADAY. Well, it is considerable. We have worked with Boeing, for example, in all their recent aircraft developments since we have had a human factors program based at Ames, more than 10 years. The association and work with the Boeing Co. in the development of the 757 and 767 was a good example in point.

I don't have a total investment that I could give you off the top of my head or what industry invests in this area, but it is substantial.

Mr. MINETA. Are they different areas than what Boeing might be doing?

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Dr. COLLADAY. Boeing and the industry as a whole takes what we learn in the Generic Human Factors Research Program and applies it to specific hardware in the development of their cockpit displays and aircraft configurations. We, just like we do in all of our research effort, work what we think is the front end of the R&T process, R&D process, and they work with us as colleagues in that research and then apply the results in new aircraft developments.

Mr. MINETA. Are there gaps that the private sector has or gaps that FAA has that NASA is picking up on and filling certain voids or are you overlapping? Is there some coordinated effort on this? You mentioned something about where Boeing picks up on what you are doing in terms of applying that to their efforts, and I saw some of that work there and they mentioned some of their cooperative efforts with NASA Ames. What about FAA and what they are doing or any other private sector efforts?

Dr. COLLADAY. It is coordinated, Mr. Mineta, with the FAA and, of course, with industry that is working with us. I don't believe there are any gaps that are not being addressed. There is certainly probably healthy disagreement over what necessary budget levels should be applied to this area, and that is a discussion that we have with the FAA as we develop and coordinate our programs, but I am not aware of any gaps that aren't being addressed at this point in our program.

Mr. MINETA. It is my understanding that Admiral Engen, the FAA Administrator, has been in touch with Dr. Graham to encourage maximum efforts in transport related human factors research. Have you been able to assure the FAA that you will be in a strong position to alleviate his concerns about diminishing NASA attention to civil aviation human factors issues?

Dr. COLLADAY. Yes, sir, I believe so. We just recently completed and all day working session on program planning for the NASA aviation safety research effort across the board with the FAA, and I believe we are responsive to Admiral Engen's concern as expressed to Dr. Graham.

Mr. MINETA. Some figures I have seen over the, let's say, last 3 years really show a drop in terms of the civil human factors study area and increase on the rotorcraft area. That is what draws my concern as I chair this other Aviation Subcommittee which has jurisdiction over the civil aircraft side, both commercial and general aviation.

As I said, my concern comes out of reading these NTSB reports and dealing with human factors. I ride jump seat practically on some portion of every flight that I take. Like Mr. Brown, I am every other weekend on a flight back to California. I talk to the crews and observe what they are doing. I had the great experience of flying those simulators you have out at Ames about 10 days ago.

But it bothers me to see any diminishing of our efforts in the whole area of general transport human factor issues, because the general public isn't that reliant on rotorcraft. This whole issue of single pilot nap of the Earth flying, et cetera, goes to the benefit of the military. I have no quarrel with that, but the problem that I see is that there is this other greater problem area. I see that effort, at least from what I perceive, to being lessened. That is what bothers me.

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Since you are going to be responding for the record, Dr. Colladay, I will look forward to that communication. As a result of that, then I can hopefully follow up with some more inquiries of your office if I might do that.

Dr. COLLADAY. Surely.

Mr. MINETA. Thank you very much, Dr. Colladay.

Thank you, Mr. Chairman.

Mr. BROWN. Thank you, Mr. Mineta.

Thank you very much, Dr. Colladay. I think we have taken enough of your time this morning. We appreciate it very much.

Dr. COLLADAY. Thank you, Mr. Chairman.

[The prepared statement of Dr. Colladay follows:]

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STATEMENT

OF

Dr. Raymond S. Colladay
Associate Administrator for
Aeronautics and Space Technology

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

before the

Subcommittee on Transportation, Aviation
and Materials
Committee on Science and Technology
House of Representatives

Mr. Chairman and Members of the Subcommittee:

It is a pleasure to appear before you today to present NASA's FY 1987 Aeronautics and Transatmospheric Research and Technology (R&T) budget requests which reflect the Administration's continuing strong commitment in this difficult fiscal environment. I believe they represent efficient and forward-looking programs that carefully consider the technical needs and opportunities facing this country's aerospace community today. The NASA R&T base is a vital element of a coordinated, National R&D effort. As a source of independent, far-term R&T, it provides new concepts, innovative ideas, and generic technology essential to U.S. leadership in aviation.

For the greater part of this century, NASA and its predecessor NACA have pioneered advanced technology for superior U.S. aircraft. This sustained long-term, fundamental research activity has yielded great payoffs for the nation, frequently leading to revolutionary new vehicle systems or capabilities. Two recent examples that I expect will write a new chapter in civil aviation are the tilt rotor and the advanced turboprop (ATP) propulsion concept.

Tilt Rotor technology, developed over the last 15 years in cooperation with the U.S. Army and presently being applied in the triservice tilt-rotor aircraft, makes it possible for an aircraft to retain the vertical flight and hover advantages of a helicopter, while maintaining efficient and smooth forward flight at speeds approaching those of current propeller driven airplanes. This capability represents an important step toward entirely new generations of high-speed rotary wing aircraft (Figure 1) which will be able to serve a variety of military and civil missions, including rescue, emergency medical

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service, and resource exploration. The increased speed, range, and payload advantages provide a new opportunity for large-scale inter-city and inter-region civil transportation, reducing urban congestion in highly developed areas and eliminating the need for a large transportation infrastructure in remote or developing regions.

Of comparable significance is advanced turboprop technology, which promises the single largest improvement in air transport fuel efficiency (Figure 2) since the introduction of the high bypass-ratio turbofan engine in the 1960's. This technology will reduce aircraft fuel consumption by up to 30 percent and lower direct operating costs by nearly 8 percent. These improvements are possible while maintaining turbofan cruise speeds, cabin comfort, and low noise levels. The rapid rate at which turboprop technology is now maturing is due in large measure to the broad technology base we have developed over the past decade, which addresses the key technical issues important to all propeller/airframe installations being considered for development by U.S. industry.

Despite the remarkable progress to date, we are now on the threshold of numerous exciting opportunities for making dramatic leaps in vehicle capabilities. Impressive progress is being made in computational fluid dynamics and structures. Recent breakthroughs are enabling realistic calculations of internal flows for propulsion applications and 3-dimensional flows about complete aircraft. Structural simulation of entire aircraft with detailed local analysis will soon be possible. Coinciding with advances in computational methods is the initial operation of the Numerical Aerodynamic Simulation (NAS) capability which is developing the world's premier scientific computational facility for aeronautical research and development. When fully operational in July 1986, this capability will greatly accelerate progress in computational fluid dynamics as well as in other important computationally intensive disciplines such as structures, materials, and chemistry. Innovative results are also rapidly emerging from our research laboratories in the areas of supermaneuverable aircraft technology; lightweight, high-temperature materials; and hypersonics, where great progress has been made in airbreathing propulsion. These advances in technology have profound significance for the future of aviation.

Transatmospheric R&T

Perhaps most visibly, these advances in aeronautics and space technologies are enabling an entirely new class of aerospace vehicles, powered by airbreathing propulsion, that have vastly superior performance to anything flying today. The Aerospace Plane as shown in Figure 3 -- part

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aircraft and part spacecraft -- will be capable of taking off from and landing horizontally on conventional runways, sustaining hypersonic cruise in the atmosphere, and accelerating into space. As the President mentioned in his State of the Union Address, a commercial transport using this technology could be developed, providing routine access to the Pacific nations in less than two hours. The extreme altitude and speed capability of this technology will make our military aircraft nearly invulnerable to attack and initial indications are that such transatmospheric vehicles will significantly cut the cost of delivering payloads to orbit. This exciting opportunity is a direct outgrowth of long-term, fundamental research in the NASA aeronautics and space R&T base, maintained over the past decade. Major technical advances have occurred which have provided the confidence for a significant growth and acceleration of technology development for an aerospace plane.

NASA is requesting $376.0 million in FY 1987 for Aeronautics R&T and $171.0 million for Space R&T as shown in Figure 4 compared with previous years' budgets. Transatmospheric R&T, which is an integral part of the joint NASA/DOD National Aerospace Plane program, is a new budget line item for FY 1987. NASA is requesting $45.0 million for focused transatmospheric R&T which is building on a strong base of fundamental research being conducted in the aeronautics and space R&T programs.

The transatmospheric activities include a combination of computational efforts, ground-based experiments, and small-scale hypersonic flight experiments (a joint effort with Sandia National Laboratories). The Aerospace Plane program elements, highlighted in Figure 5, are focused on developing and validating the critical technologies. The key enabling technology is airbreathing propulsion. Propulsion concepts for this application must function efficiently over a wide speed range -- from zero speed for takeoff to Mach 12 or even to near orbital velocities. Hybrid engine concepts have been identified that when integrated with a supersonic combustion ramjet or SCRAMJET have the potential to perform effectively over the entire speed range. The airframe and propulsion system must have high strength and low weight thermal structures to withstand repeated exposure to extreme heating loads during sustained hypersonic flight in the atmosphere. For ascent into orbit, peak temperatures could rise to 5000°F in some areas, requiring the development of advanced materials and active cooling technology. Perhaps one of the greatest challenges for this class of vehicles is the integration of the highly interdependent airframe and propulsion system. The maturation of key technologies including the development and testing of propulsion system modules and airframe components will lead to an assessment of technology readiness in 1989, prior to any decision to

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proceed with an experimental aircraft. During FY 1987, comprehensive design studies involving the aerospace industry will explore the application of these and other advanced technologies to future high-speed civil transportation systems.

Recent accomplishments that enable realistic consideration of these ambitious goals are flowing from many key technology areas. Langley Research Center has demonstrated, up to the ground test facility limit of Mach 7, sufficient SCRAMJET engine thrust (Figure 6) to propel a large aircraft at hypersonic speeds. Two of our major facilities for propulsion testing are currently being modified to expand their capabilities; the 8-foot High Temperature Tunnel at Langley for large-scale and multiple-module SCRAMJET tests and the Propulsion System Laboratory (PSL) at Lewis Research Center for subsonic and supersonic system tests. An advanced carbon-carbon material has also been developed with high-emissivity, oxygen-resistant coatings. These materials promise substantial weight reduction for high-temperature leading edge and control surface structures. Techniques for foil-gage fabrication and vacuum sealing of superalloy (Figure 7) and metallic composite structure have been improved sufficiently to consider in the design of lightweight, hot structures for airframes and engines.

The advanced NAS capabilities are becoming available just in time to support the enabling CFD analysis and design activities for the National Aerospace Plane program. The NAS facility at the Ames Research Center and other large supercomputers will provide the necessary computing power to analyze the complex flow interactions of airbreathing propulsion systems and external aerodynamics. Important advances in computational modeling provide the ability optimize the vehicle configuration and propulsion system integration and to analyze the transatmospheric class of vehicles in areas where ground test facilities are inadequate. Recent calculations showing pressure distribution in a hypersonic inlet duct are depicted in Figure 8.

Extending research from experiments in the laboratory to flight has long been recognized as a necessity for the development and validation of hypersonic/transatmospheric technology, since ground test facilities are inadequate. Notable examples begin with the development and flight test of the X-15 (Figure 9) in the 1950's, the lifting body (Figure 10) programs in the 1960's, and most recently the Space Shuttle. This extension to flight will be particularly necessary for the aerospace plane, where integration of the highly interdependent airframe and propulsion system and vehicle performance validation throughout this broad flight envelope will require an experimental aircraft, or X-vehicle. With the potential

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for a major revolution in air and space transportation at hand, NASA plans to move very aggressively.

Emerging Technologies

In addition to the Aerospace Plane, there are remarkable opportunities in aeronautics technology for making order-of-magnitude advances in future vehicle capabilities. A broad program of basic R&T focused in emerging technology areas is essential if these new advances and breakthroughs are to occur. This will also lead to additional and perhaps even more important developments which are just now being identified. I would now like to touch briefly on a few such items in the FY 1987 budget request that I believe have special potential for affecting our military and civil capabilities as well as the U.S. competitive posture.

An area of extreme importance for analysis and optimization of all future vehicles is numerical simulation. Tremendous progress is being made in computational fluid dynamics (CFD) for both internal (propulsion) and external (aerodynamic) flows. An important breakthrough has recently been made in the simulation of flow through the rotating turbomachinery of an airbreathing propulsion system. This "first ever" calculation of the flow interactions between moving and stationary blades was enabled by a major advance in interfacing a moving grid to a stationary grid. Figure 11 graphically portrays the calculated supersonic flow through compressor blade rows. Future efforts will center on extending the analysis to a full three-dimensional flow simulation which will have a major impact on compressor/turbine performance and on the efficiency and reliability of both airbreathing and rocket propulsion systems. In external flow simulation, three-dimensional viscous flow techniques for complete aircraft configurations are progressing rapidly. These efforts are being lead by new, fast algorithms for generating computational grids which permit more detailed calculations in areas where rapid changes in the flow take place. Figure 12 illustrates the grids recently generated for an F-16 aircraft. This grid generation is highly dependent upon accurate geometric modeling of the aircraft surfaces. Recent innovations have enabled rapid generation of accurate three-dimensional surface models of complex aircraft as shown in Figure 13. We are now aggressively pursuing viscous flow simulation and experimental verification about complete aircraft, a capability which is crucial to the design of highly integrated military aircraft and the Aerospace Plane. Solutions for the full Navier-Stokes equations may also open the way for a broad range of control mechanisms for favorably altering aerodynamic flows.

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Progress in CFD is expected to accelerate as the Numerical Aerodynamic Simulation (NAS) capability becomes fully operational in July 1986. All elements of the Initial Operating Configuration (IOC) have been installed and successfully acceptance tested. The centerpiece of the IOC system is the Cray 2 supercomputer (Figure 14). The NAS machine is currently the world's largest and most powerful scientific computer, containing more memory than all of the approximately 100 computers that Cray Research has delivered in the past combined. It can perform up to 1.5 billion floating point operations per second. Limited pathfinding computations on the Cray 2 have already begun, including aerodynamic and propulsion computations for the Aerospace Plane. Planning for the Extended Operating Configuration (EOC) is in progress and acquisition of the second high-speed processor, which will be four to six times more powerful than the Cray 2, is planned for FY 1987. Additionally, the Long Haul Communications subsystem, to increase remote user access, will be expanded and the secure processing area in the NAS facility completed.

The exploitation of NAS and the next generation of large-scale parallel processing computers for structural analysis will enable more efficient, lightweight, and cost-effective aerospace structural systems. A growing computational structural mechanics activity is concentrating on the development of numerical techniques to analyze and optimize a complete aircraft structure, including the capability for local detailed analysis of critical components within larger computational models. The detailed stress analysis of complete aircraft under operational loads, as shown in Figure 15, is particularly challenging because of the size and complexity of the numerical models.

NASA is also applying experience in computational modeling to the serious safety problem of low-altitude wind shear occasionally experienced by aircraft during takeoff and landing. Analytical models, such as presented in Figure 16, permit the calculation and display of microburst airflows and their interactions with aircraft. The intensity and altitude of simulated wind shear conditions can be varied and fed into digital flight simulators. These simulators are now being used to train pilots and to develop cockpit instrumentation which will alert flight crews of danger and also aid them in safely handling these dangerous encounters. In FY 1987, NASA and the FAA plan to pursue a cooperative research program addressing airborne wind shear detection, avoidance, and survivability. Emphasis will focus on characterizing the microburst phenomena, determining heavy rain effects on aerodynamic lift, and improving aircraft response in severe wind shear.

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In FY 1987 NASA will continue research in advanced composites, focusing on a new generation of materials and design approaches for up to a fifty percent weight reduction over existing structures. Significant effort will be devoted to the development of advanced concepts and configurations which exploit the unique properties of composites. These unconventional structural designs require a better understanding of material properties, loading effects, and failure mechanisms as well as the development of 3-dimensional structural analysis methods. In addition to the development and characterization of new thermoset and thermoplastic resin systems, research will concentrate on effectively using advanced material forms and fabrication technology, such as 3-dimensional weaving, to increase damage tolerance and strength.

In an area which promises a leapfrog in future military aircraft performance, the Langley Research Center has established the feasibility of propulsive flight control as a design option through simulator and free flight tunnel research. This concept is the result of many years of NASA research into fighter aircraft aerodynamics and controllability at high angles-of-attack. Research results include safe maneuvering flight at angles-of-attack approaching 80 or 90 degrees, as demonstrated by the F-18 model in Figure 17, and highly efficient supersonic cruise designs. Analytical and experimental research indicate that a fighter aircraft utilizing this technology would have a significant combat advantage over a conventional aircraft, and that statically unstable, highly efficient aircraft designs could achieve levels of maneuverability far exceeding current fighters. NASA plans to accelerate the development of the key enabling technologies.

Flight Research Programs

NASA is conducting several major systems technology programs. Two of these, the Advanced Turboprop (ATP) and X-Wing programs will be reaching significant milestones in FY 1987.

The Advanced Turboprop (ATP) program (Figure 18) is progressing toward an early FY 1987 flight test of a large-scale, single-rotation propeller to provide scale verification of the blade structures, aerodynamics, and acoustics. The flight test, being conducted under contract with Lockheed Georgia, will build on the extensive NASA single-rotation model data base. This technology base developed during the past decade in the NASA program has resulted in a rapidly expanding industry effort to develop turboprop technology for product application in the early 1990's. In light of the accelerating industry activities, the ATP program for FY 1987 and beyond is being modified. The single-rotation

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flight test matrix has been reduced and the acoustically treated cabin environment investigations have been eliminated. NASA will pursue fundamental technology efforts that take advantage of planned industry flight tests in the area of cabin environment technology. Other technology development activities include counter-rotation propeller testing to improve performance and reduce noise at take-off and cruise flight conditions, and verification of installation aerodynamic codes and determination of aircraft stability and control using improved models. Large-scale ground tests of the General Electric unducted fan, a gearless counter-rotation concept, will be completed in FY 1986. The modified NASA ATP program, with expanded participation by industry, will provide the fundamental data base and technological foundation necessary for future industry product development.

The X-Wing concept, pictured in Figure 19, has the vertical lift capability of helicopters while providing the range and speed abilities of fixed-wing aircraft. It has a four-bladed, extremely stiff rotor utilizing circulation control aerodynamics for lift and control. When the rotor is stopped in forward flight, it forms a fixed, X-Wing configuration. In this stopped-rotor configuration, the helicopter-type vehicle becomes almost a conventional aircraft and can achieve transonic speeds. The primary objective of the joint DARPA/NASA Rotor Systems Research Aircraft (RSRA)/X-Wing flight test program is to demonstrate X-Wing conversions from rotary-to fixed-wing flight and back to rotary-wing flight. Fabrication of the X-Wing rotor system and modification to the RSRA are progressing, with an aircraft rollout scheduled later this year. The propulsion system testbed and ground based data management systems have been completed and are operational. A forty hour flight test program will be initiated in early FY 1987 to investigate the dynamic stability, performance, and rotor control characteristics of the X-Wing rotor system -- from 100 knots in the helicopter-mode, through conversion to fixed-wing forward flight of 250 knots. The flight program is planned for completion in late FY 1987.

In a related area, the rotorcraft R&T program is focusing on the key problems that severely limit the vehicle's civil and military usefulness. The rotorcraft program will be augmented in FY 1987 to develop and verify accurate prediction methods and to explore new concepts for an eighty percent reduction of noise and vibration. Part of that effort will be the first comprehensive flight test of pressure-tapped blades to gather airloads data. The Boeing Model 360, a company-developed 200 knot helicopter, will be used. These efforts will address the difficult problem of predicting the airloads that are the source of noise and vibration. This program builds on cooperative basic research (Figure 20) with industry and the U.S. Army conducted over the past three years.

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Discipline Research

The FY 1987 budget request also provides a solid base of long-term discipline research from which future military and civil advances will flow that involves universities, other government agencies, and industry as well as NASA researchers and facilities. I plan to briefly describe the key elements of the aeronautics R&T base, emphasizing important directions for FY 1987.

Aerodynamics

The aerodynamics program (Figure 21) is aimed at improved methods for analyzing and predicting aerodynamic phenomena, and at the development and validation of advanced aerodynamic configuration concepts. The computational and the maneuverability programs have previously been addressed. Two additional significant thrusts involve drag reduction and propulsive lift. Approximately 50% of a subsonic transport's fuel goes to overcome drag caused by skin friction. A number of passive turbulent drag reduction concepts, which have shown promise in wind tunnel tests, are being studied intensely for practical application throughout the speed range. For example, active laminar flow control techniques that reduce the skin friction drag by 20 to 30% for subsonic transports are currently undergoing flight evaluation. Propulsive lift concepts such as ejector lift/vectored thrust are being developed for supersonic short take off and vertical landing (STOVL) fighter aircraft. In one such program, NASA will test a large-scale Canadian model of an ejector lift/vectored thrust fighter in the newly repowered 40X80 foot wind tunnel at the Ames Research Center. With respect to general aviation, focus will shift from single-engine aircraft to spin-resistant design concepts for twin-engine configurations.

Materials and Structures

The materials and structures program (Figure 22) is providing the technology base for advanced structural materials, concepts, and analytical methods for future airframe and engine systems. In FY 1987, emphasis will be placed on enabling technologies for high-speed aircraft. These include fundamental research in ceramics and high-temperature composites for engine applications and advanced honeycomb, metal matrix and stiffened hot structures for airframes. Multidisciplinary structural analysis and optimization techniques will also be emphasized as key to high performance vehicle design. These advanced aircraft, with very efficient, highly flexible structures coupled with high operating temperatures and pressures, may encounter severe aeroelastic flutter and flight instabilities. Research will investigate aeroelastic response over the entire

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flight regime.

The Hot Section Technology (HOST) program will continue to develop life prediction methodology for turbine engine components. In FY 1987, the activity will focus on 3D structural analysis of turbine blades and the development of life prediction models for components subject to thermomechanical fatigue.

Aeropropulsion

Current propulsion research encompasses a wide range of technologies that promise more effective research tools, engine components, and system capabilities. The propulsion R&T program (Figure 23) is founded on fundamental technology development in materials and structures, internal computational fluid mechanics and instrumentation. Propulsion instrumentation research provides the enabling technology to make flowfield and structural measurements in complex, high-temperature environments for improved understanding and verification of analytical codes. A recent development is a new Laser Doppler Velocimeter which allows measurement from a single viewing port of all three velocity components of the flow in the rotating blade rows of turbomachinery without disturbance. This instrumentation will be used with an advanced three-stage compressor in FY 1987 to investigate secondary flow strength, which may have a large adverse effect on compressor efficiency.

A major study has shown that small engine efficiency improvements approaching 50% may be achievable with application of advanced materials, structures and components. Detailed flow measurements of a large, low-speed centrifugal compressor will be made to provide a better understanding of component flow physics for use in developing advanced components and computational codes. In propulsion technology applicable to military aircraft, a complete ejector system for powered lift will be tested to determine the flow distribution and pressure drops.

Information Sciences and Human Factors

Research in information sciences, controls and guidance, and human factors (Figure 24) is focused on the integration of human/computer systems for advanced aircraft. This research in conjunction with aircraft automation and artificial intelligence technology developments will be applied on board the aircraft to improve safety and efficiency and facilitate the integration of aircraft into the modernized National Airspace System. The application of automation technologies is being explored in aircraft crew station designs where massive amounts of information such as collision threats, adverse weather, navigation data and

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route options, and aircraft system status must be effectively transferred to the pilot. In high-performance aircraft, they are being applied to an automated wingman concept to enhance combat aircraft effectiveness, and in rotorcraft to automated nap-of-the-earth flight.

Integration of advanced concepts into a unified, automated airspace system will have significant payoffs for aircraft safety. Research in human engineering methods and human/crewstation designs is aimed at exploiting automation to improve transportation safety. NASA will continue to develop statistics on flight safety based on data from the Aviation Safety Reporting System to guide our safety research efforts.

Flight Systems

The flight systems and high-performance flight research programs (Figure 25) complement the NASA and DOD research and technology base activities to ensure that emerging technologies and advanced concepts are validated in flight and that a flight data base is available to refine and verify predictive techniques.

The NASA/DARPA X-29A forward-swept wing aircraft is the first manned experimental high-performance aircraft to be fabricated and flown in many years. This aircraft incorporates many of the advanced technologies being considered for the next generation of fighter aircraft. During its first year of flight test operations, the aircraft has achieved an exceptional record of performance. The initial design point, Mach 0.9 at 30,000 feet altitude, was achieved this past month. We plan to reach the second design point, Mach 1.2 at 30,000 feet altitude, in May of this year and to complete the envelope expansion in September. A joint NASA, DARPA, and Air Force flight research program to more fully exploit the technologies designed into the X-29A is planned in FY 1987. Highly integrated aircraft such as the X-29 and the Aerospace Plane require extensive ground testing and analyses of system interactions in support of the flight research. An Integrated Test Facility is planned as part of NASA's FY 1987 Construction of Facilities program to address this important requirement.

Preparations leading to important future flight research activities are continuing. NASA has modified a Navy F-18 aircraft for flight research at high angles-of-attack. The flight program will focus on the measurement of forebody aerodynamics with vortex interactions for angles-of-attack up to 80 or 90 degrees. The NASA/Navy Oblique Wing preliminary design will be completed this year providing the basis for modifications to the F-8 testbed aircraft. Flight testing will be initiated in 1989. In addition, an advanced supersonic STOVL activity

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in cooperation with DOD and the United Kingdom is underway. System studies are planned to identify the most promising STOVL airframe and propulsion concepts for potential further technology development.

Summary

The NASA research establishment has required decades to develop, and has played a major role in establishing and maintaining U.S. leadership in aeronautics. We have a strong commitment to continuing NASA's central role in research and technology. The foundation for future contributions is the excellence of our institutional capabilities. With the constraints on the federal budget, we can neither pursue all attractive opportunities nor be lulled into seeking small incremental gains. Tough programmatic decisions will continue to lead to curtailment or even elimination of good research in favor of even higher payoff activities. The NASA aeronautics program is identifying and concentrating on key emerging technologies that promise order-of-magnitude advances. As we look at where those advances are likely to occur, I expect that we will continue to put more emphasis on the high-speed flight regime to extend U.S. leadership in aeronautics and space.

It is essential for the continued growth and prosperity of U.S. aeronautics that government, industry, and universities approach our aeronautics future with vision. The recently established National Aeronautical R&D Goals provide a framework for focusing planning and research efforts. I believe that the FY 1987 budget request will enable NASA to continue to provide the necessary technological foundation and leadership for securing the exciting capabilities we have described. We appreciate this Committee's long-standing support and commitment to aeronautics research, and look forward to working with you to strengthen this area that is so crucial to the future economic and defense security of this country.

Thank you Mr. Chairman.

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Figure 1: Civil Tilt-Rotor Aircraft Concept

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Figure 2 Advanced Turboprop Powered Aircraft Concept

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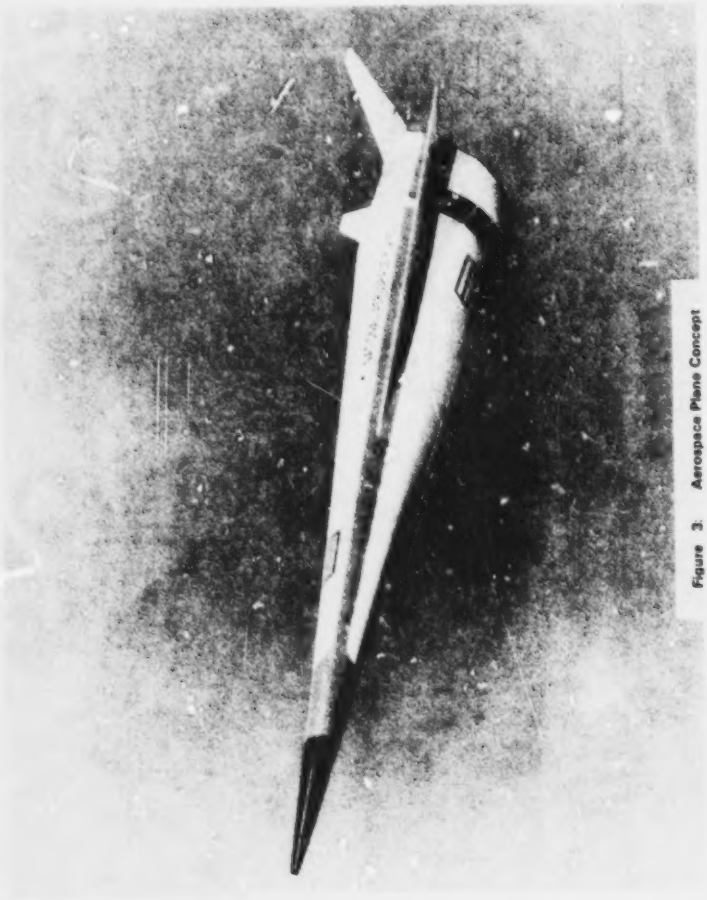

Figure 3. Aerospace Plane Concept

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OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY

R&D BUDGET

	$, MILLIONS			
	FY 1985	FY 1986		FY 1987
	ACTUAL	BUDGET ESTIMATE	CURRENT ESTIMATE	BUDGET ESTIMATE
AERONAUTICS RESEARCH & TECHNOLOGY	342.4	354.0	354.0	376.0
R&T BASE	(223.3)	(239.3)	(240.3)	(272.9)
SYSTEMS TECHNOLOGY	(119.1)	(114.7)	(113.7)	(103.1)
SPACE RESEARCH & TECHNOLOGY	145.1	160.0	160.0	171.0
TRANSATMOSPHERICS R&T (NATIONAL AEROSPACE PLANE TECH.)	—	—	—	45.0

Figure 4: Aeronautics, Space, and Transatmospheric R&T Budgets

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AEROSPACE PLANE TECHNOLOGY ROADMAP

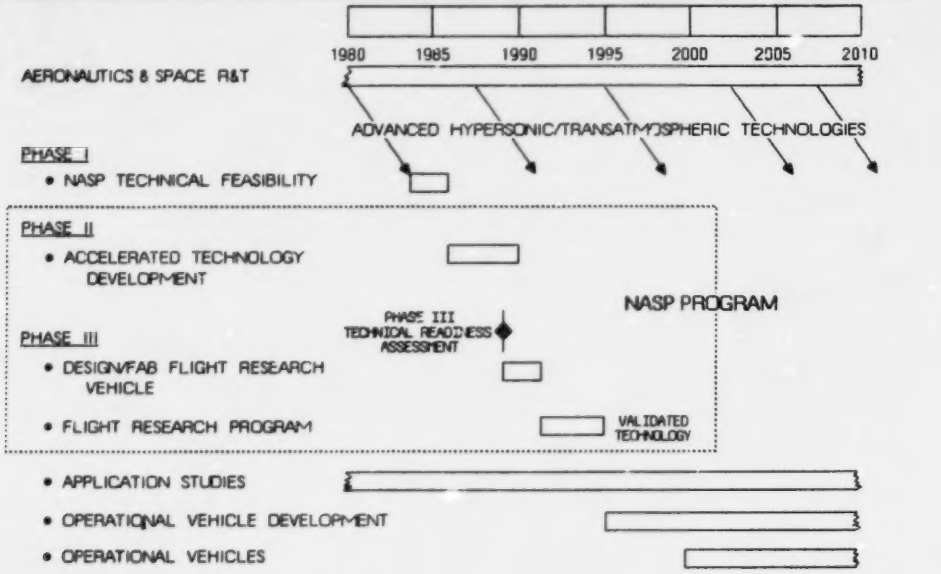

Figure 5: National Aerospace Plane Program

Figure 6: Supersonic Combustion Ramjet (SCRAMJET) in Test Facility

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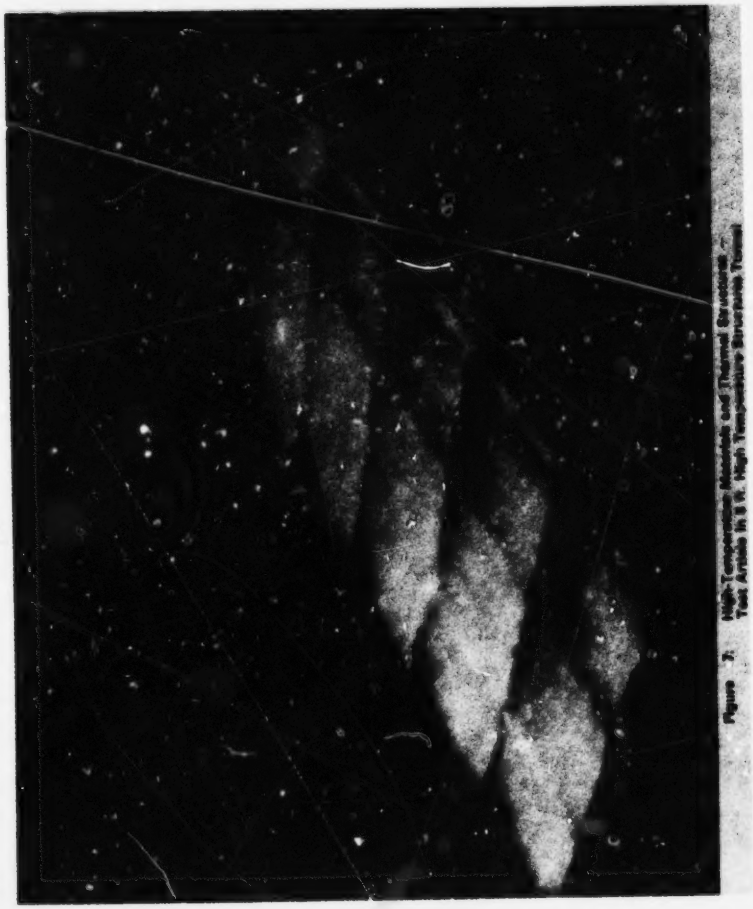

Figure 2. High Temperature Nozzle and Thermal Structure Test Article in 8 ft. High Temperature Structures Tunnel

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Figure 8: Computation/Design Methods – Static Pressure Profiles in High-Speed Duct Flows

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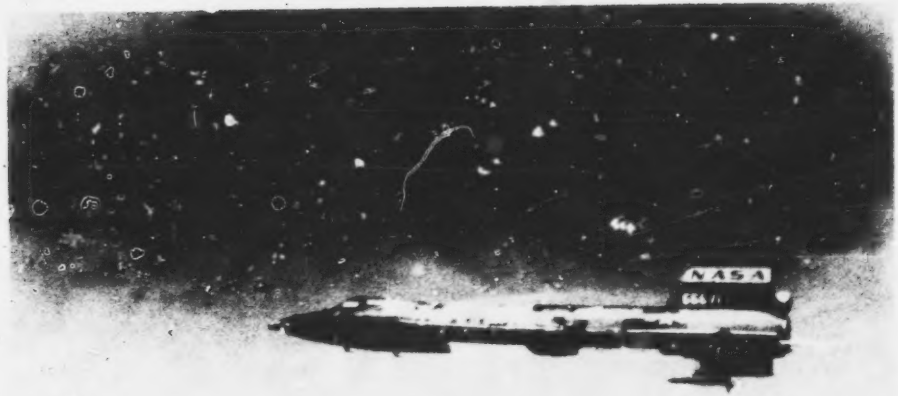

Figure 9. Hypersonic Flight Research -X-15 Airplane

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Figure 18. Re Entry Lifting Body Aerodynamics Background – X-24

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Figure 11: Internal Computational Fluid Mechanics – A Simulation of Rotor-Stator Interaction

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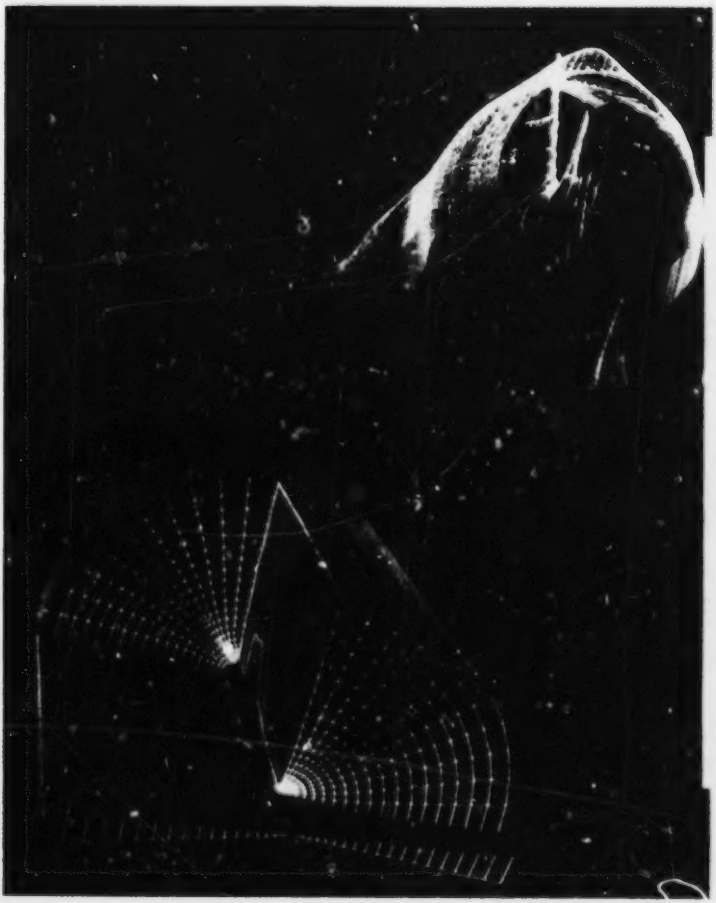

Figure 12 Grids for Computational Fluid Dynamics Modeling of External Flows

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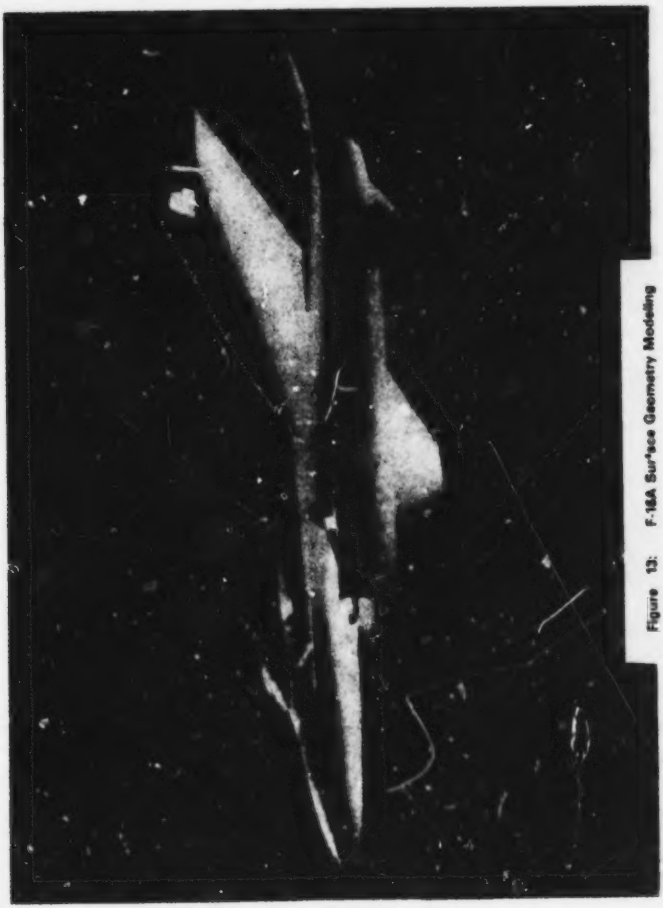

Figure 13: F-18A Surface Geometry Modeling

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Figure 14. Numerical Aerodynamic Simulation (NAS) Program Picture of Cray 2 Computer

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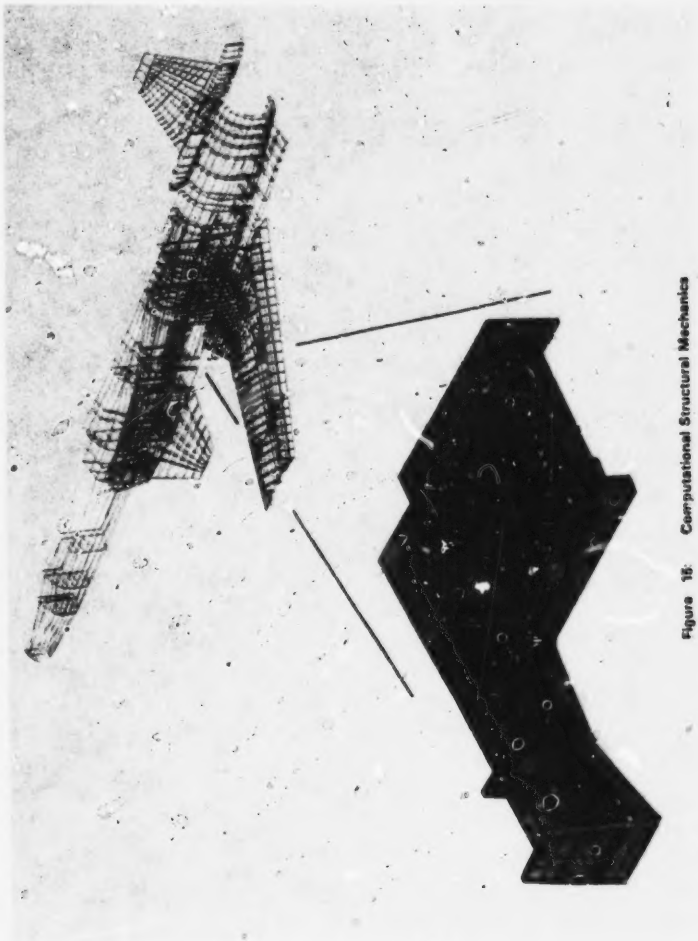

Figure 18: Computational Structural Mechanics

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Figure 18. Wind Shear Modeling

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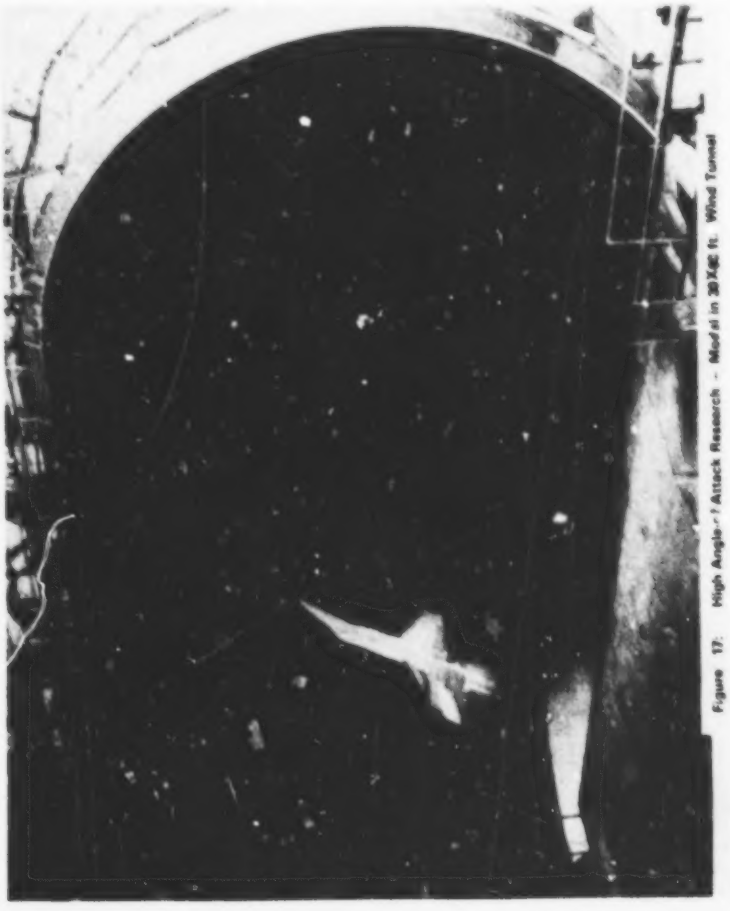

Figure 17. High Angle-of-Attack Research - Model in 30 X 60 ft. Wind Tunnel

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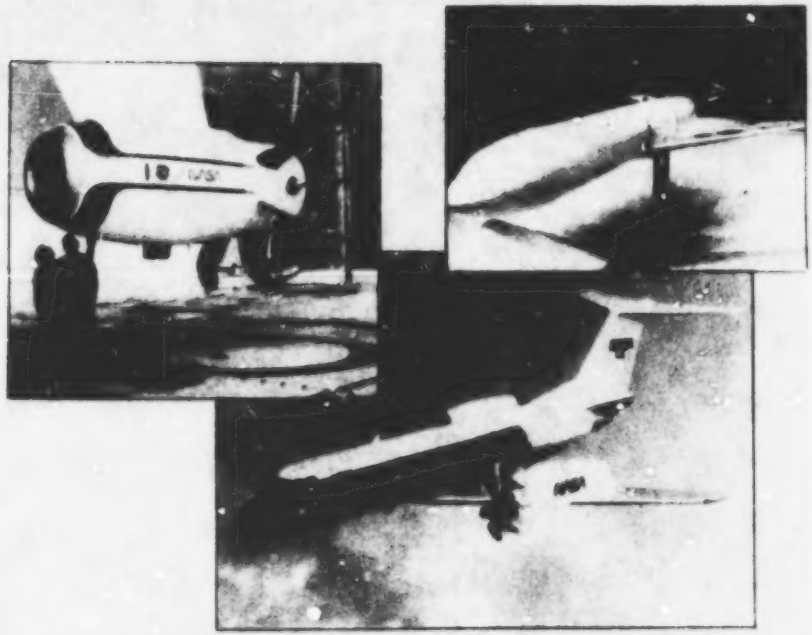

Figure 18: Advanced Turboprop Research

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Figure 19 Rotor Systems Research Aircraft (RSRA)/X Wing Concept

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AERODYNAMICS

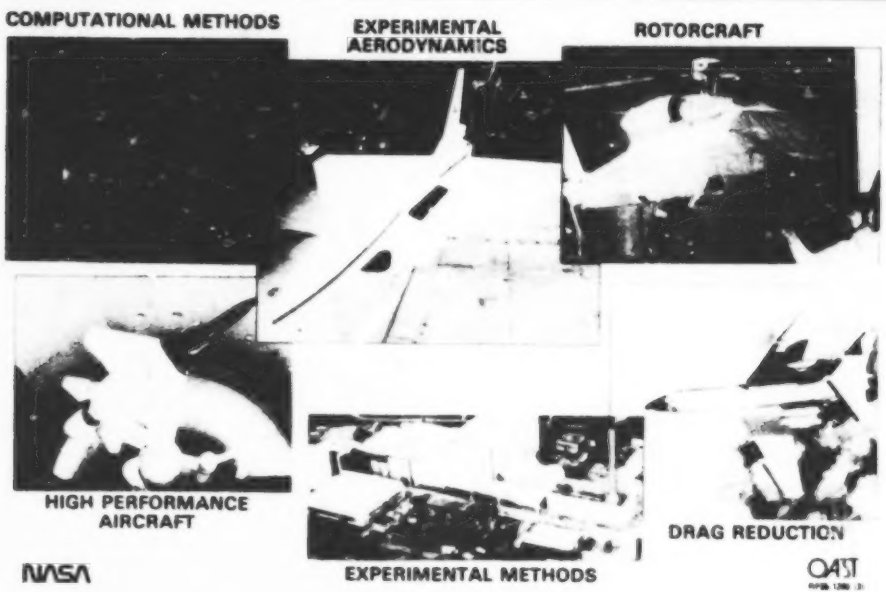

Figure 21 Aerodynamics R&T

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MATERIALS AND STRUCTURES

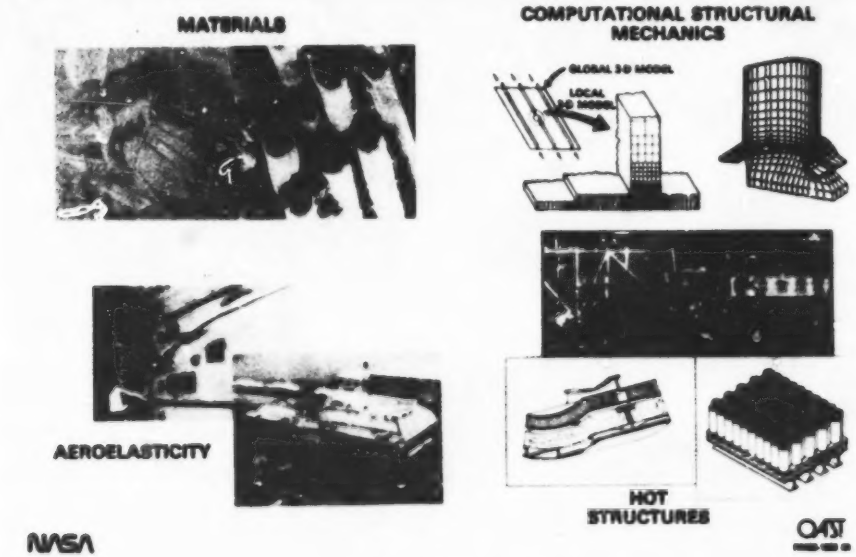

Figure 22 Materials & Structures R&T

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AEROPROPULSION

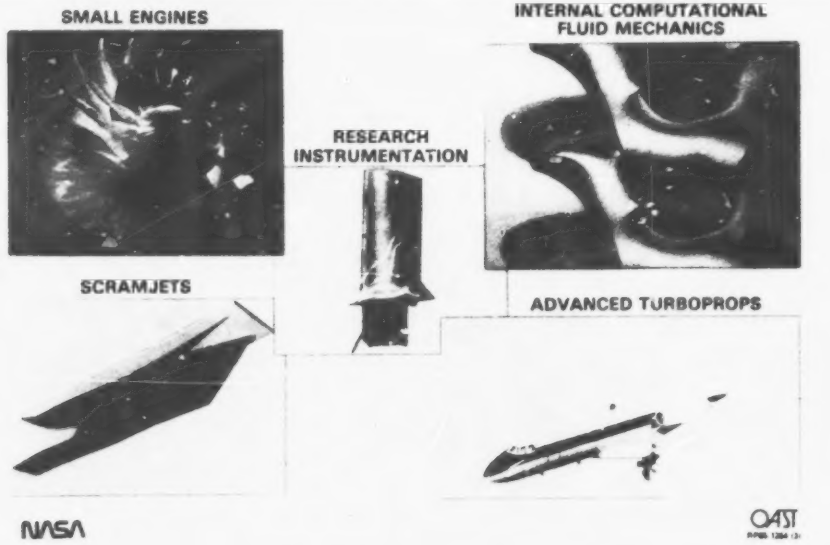

Figure 23. Aeropropulsion R&T

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INFORMATION SCIENCES AND HUMAN FACTORS

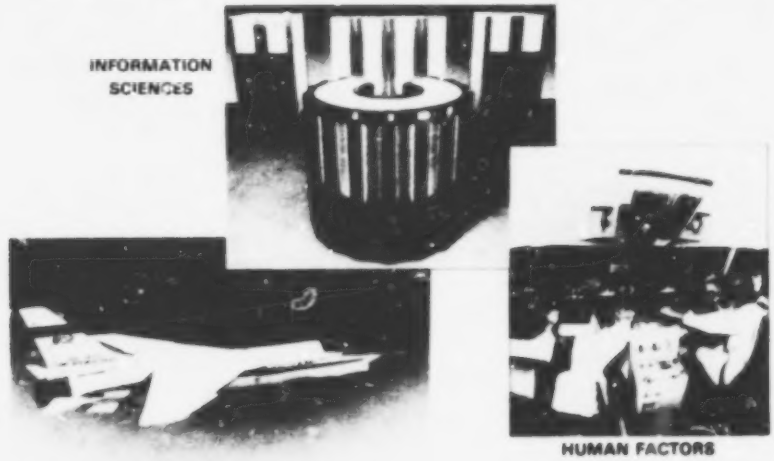

Figure 24 Information Sciences and Human Factors R&T

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FLIGHT SYSTEMS

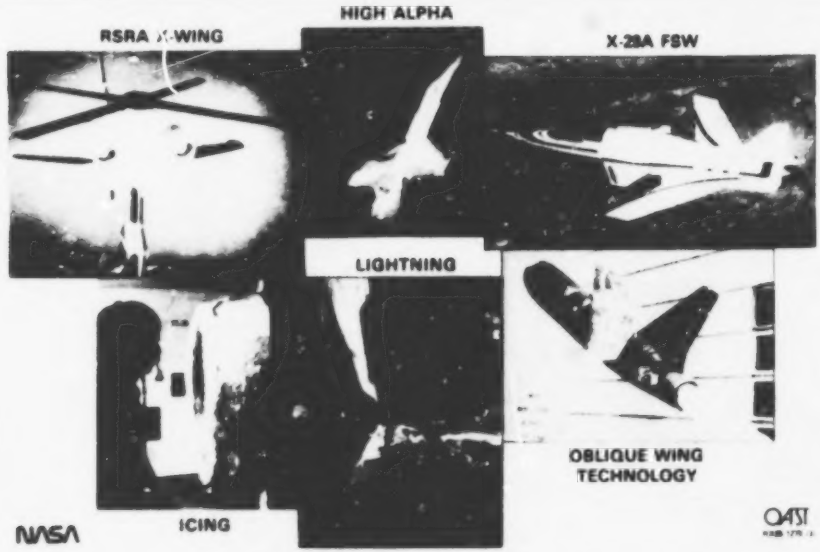

Figure 25 Flight Systems R&T

Mr. BROWN. Our next witness is Dr. Robert Duncan, Director of DARPA, accompanied by an able assistant whom you will introduce in glowing terms.

Dr. DUNCAN. Yes, Mr. Chairman. I have brought with me Mr. Robert Williams, Bob Williams, who is the program manager in DARPA for the National Aerospace Plane Program.

Mr. BROWN. We welcome both of you here this morning.

Dr. DUNCAN. I have, Mr. Chairman, a written statement that I would like to submit for the record.

Mr. BROWN. Without objection, it will be included at this point.

STATEMENT OF ROBERT DUNCAN, DIRECTOR, DEFENSE ADVANCED RESEARCH PROJECTS AGENCY, U.S. DEPARTMENT OF DEFENSE; ACCOMPANIED BY ROBERT WILLIAMS, PROGRAM MANAGER, NATIONAL AEROSPACE PLANE PROGRAM

Dr. DUNCAN. It is a pleasure for me to appear before this subcommittee to discuss the Defense Advanced Research Projects Agency's participation in the National Aerospace Plane Program.

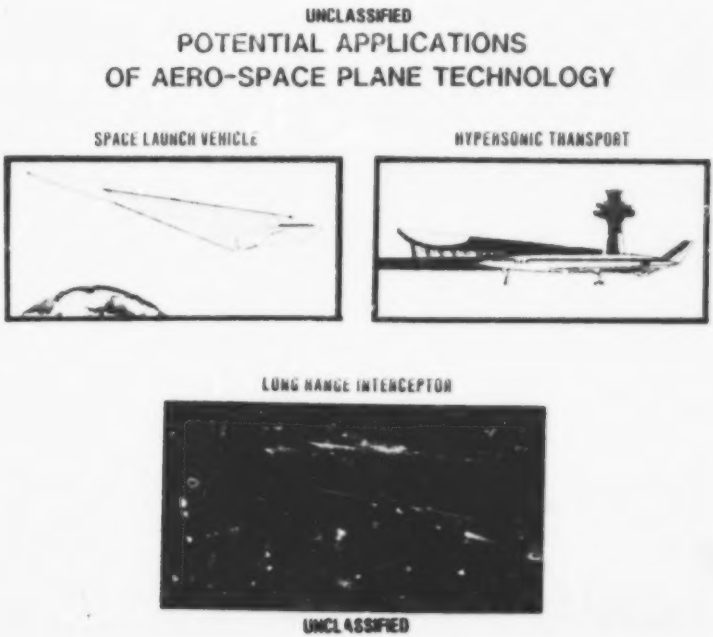

CHART 1

The first chart (chart 1) shows potential applications of this system. It is a space launch system, a potential follow-on successor

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to the shuttle, and commercial transportation, as Dr. Colladay talked about. Military applications include long-range interceptor, supersonic missile systems, and advanced bomber applications.

The National Aerospace Plane Program is not a single purpose technology program. Rather it is a technology that could have multiple civil and military applications.

ATMOSPHERIC FLIGHT ENVELOPES

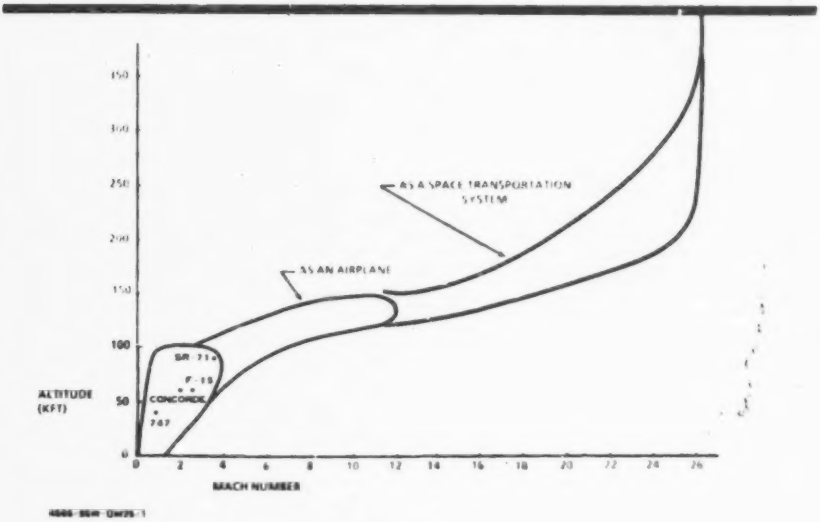

CHART 2

This chart (chart 2) shows the atmospheric flight envelop where mach number is shown as the abscissa up to mach 25 and altitude is shown on the ordinate that leads into orbital altitudes. Current aircraft as shown on this chart are points of operation for the SR-71, the Concord, the 747, and other air breathing high performance aircraft today.

It is pretty obvious that the National Aerospace Plane Technology Program advances the envelop of atmospheric flight enormously from what we do today in mach number and in altitude operations, a single stage to orbit potential.

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KEY AERO-SPACE PLANE TECHNOLOGIES

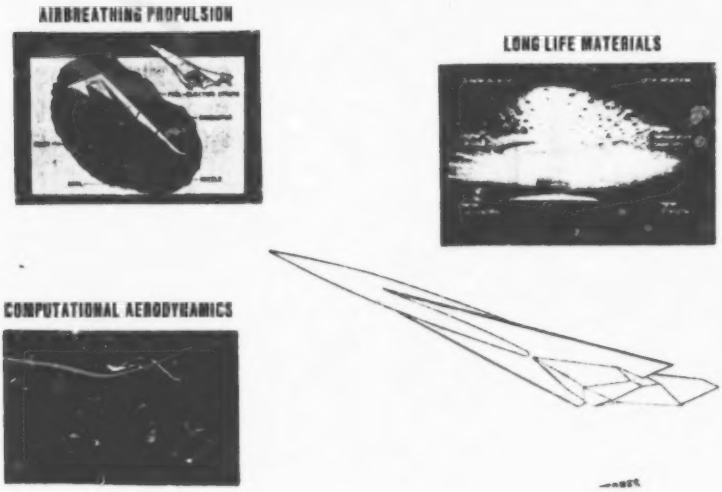

CHART 3

The next chart (chart 3) shows the key aerospace plane enabling technologies. Dr. Colladay referred to these. These are the technologies which we believe are coming together now to make the aerospace plane possible. Long life structural materials are pictorially shown, one example in the upper right hand corner. Air breathing propulsion is without question one of the greatest challenges of the national aerospace plane system. Computation aerodynamics Dr. Colladay referred to.

Here we have a system in which the aircraft and the propulsion system, the engine, are integrated in ways that are far beyond any integration we have ever had in the past. The interaction of the engine and the airframe require that we expand the analysis portion of the development far beyond that which has been done before.

The airplane in itself is in effect a flying engine. The forward portion serves as part of the compressor stage for the engine and the aft part of the aircraft is part of the expansion stage.

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NATIONAL AERO-SPACE PLANE PROGRAM

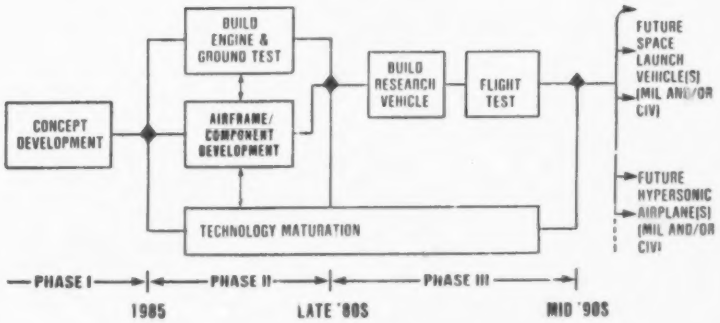

CHART 4

The next chart (chart 4) shows in simplified form the program schedule. Phase 1 was the concept development, and that led up to the decision point last fall that we should proceed with this as a national program, a joint DOD-NASA Technology Program.

Phase 2 is the second phase of a three-phase program. During phase 2, we will try to understand whether the technology is in fact viable. We are going to be building engines and ground testing them, and we are going to be developing airframe components, and we are going to be determining the feasibility of building one or more research flight vehicles.

Phase 3 would be the phase of building such vehicles and flying them, the X-31 vehicle that Dr. Colladay referred to. This could lead to a whole family of aerospace vehicles for a whole family of applications.

The program is a high risk program in the sense that the technologies have not yet been developed. It is our strong opinion that there are no show-stoppers, as Dr. Colladay said, and that we should proceed with this as a national program. It is a team effort with participation from industry, from the universities, from the research laboratories, and from the Government.

The Government includes NASA, the Air Force. The Air Force has overall responsibility for the program. It includes the Navy and DARPA, the Defense Advanced Research Projects Agency, which is somewhat like a corporate research laboratory in the Defense Department. DARPA under Mr. Williams as program manager led this during phase 1 and does have the lead responsibility during phase 2 of the program.

Just this Monday, we made the source selection announcement, a joint NASA-DOD announcement of the selection of the airframe and the engine contractors. We are now prepared to proceed with a program that we think is in the best interests of the country and

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will have an evolutionary impact on the way of life of all citizens of the world.

This ends my comments, Mr. Chairman.

Mr. BROWN. Thank you very much, Dr. Duncan.

With regard to those contracts which you announced earlier this week, would you describe those in a little bit more detail, and to what degree does this carry us through the various phases that you have described? Does this take us through phase 1 of phase 2? You say it doesn't get us into phase 3 yet.

Dr. DUNCAN. Well, these are phase 2 contracts. We released the engine contracts to—are you interested in the actual organizations, Mr. Chairman, that received the contracts?

Mr. BROWN. No, not particularly. I just want to get an idea of the timeframe. Are these short- or long-term contracts? I think, reading over the announcement hastily, I saw that—oh, yes, in excess of $450 million over a 42-month period.

Dr. DUNCAN. Yes. These are the phase 2 contracts. We selected a variety of contractors and will be down-selecting as we proceed through phase 2, down-selecting in terms of the number of industrial participants in the program.

Mr. BROWN. So, this assumes a continuation of funding over the next 3 or 4 fiscal years at the levels that you have programmed.

Dr. DUNCAN. Yes. Incidentally, Mr. Chairman, this program started with our own internal funds in the sense that we reprioritized within our organization in the phase 1 part of the program because we felt that the potential was so great that this should have a high priority in what we were doing. It is not until we entered into this next phase that we have developed the joint funding concept as we enter the phase of having large scale industrial participation.

Mr. BROWN. Dr. Duncan, my sense is that there is enthusiastic support for the program among many Members of Congress. There is also the beginnings of a considerable amount of sniping at it from the standpoint of do we need to start this program at this point, is it that high a priority, and so forth.

I wish you would speak to that subject a little bit, because we are going to be called upon to answer these kinds of questions in some detail. You know what the current budget situation is as well as anybody. Tell us how to respond to that.

Dr. DUNCAN. Well, by the end of the century, the current shuttle fleet will be nearing the end of its useful life. Given the usual length of our systems development process, 12 to 15 years from go ahead to operations, we should have started several years ago in a program such as this. In fact, within DARPA, we did start 3 years ago with our own internal investigation.

But the technology—it is a technological pace program, as Dr. Colladay indicated. We believe the technology is there. We are sticking our necks out to a certain point, but we believe the technology is there that we can indeed develop a system that can perform as we are projecting that it would perform.

Mr. BROWN. This line of argument relies upon the need for replacement for the shuttle rather than further incremental improvements in the present shuttle technology. To what degree can we emphasize this argument? Are we going to be pursuing this

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technology as a replacement for the shuttle, and are we, at the same time, going to be trying to perfect the shuttle, shall we say, so that it could be used for a further generation at the same time?

Dr. DUNCAN. Well, I used the shuttle, Mr. Chairman, only as an example of a NASA program.

Mr. BROWN. Correct. I was going to ask you for the Defense Department aspects of it also.

Dr. DUNCAN. The Defense Department applications we are very excited about and we feel it is very necessary that we proceed with those. The SR-71 has been with us for a very long period of time. There are other military needs that I am not free to discuss that we feel it is very important that we proceed with this program.

The shuttle is an important aspect of it, but it goes far beyond the shuttle alone, Mr. Chairman.

I don't know whether I have answered what you had in mind or not.

Mr. BROWN. You haven't been very definitive, frankly, but I think I understand the reasons for it. We want to have the military have the capability to command the upper reaches of space, obviously, for a number of reasons which are important to the military.

Can you deal specifically with the question of the role that this would play in connection with the possible deployment of a space defense initiative type system?

I am trying to identify several lines of argument here and give them their relative importance in such a fashion that we can develop a coherent case for maintaining this program.

Dr. DUNCAN. Yes, Mr. Chairman. There are five partners in this program, four of whom are DOD partners and one of whom is NASA. One of those four DOD partners is the SDI organization. They are providing funds to the program. They are involved in the program to the extent that all the same high level of participation as all five partners.

Mr. BROWN. Would you identify the other four DOD participants?

Dr. DUNCAN. Yes, sir. DARPA, the agency that Mr. Williams and I represent, the Navy, the Air Force which has the lead responsibility for the overall program, and SDI.

Mr. BROWN. And has there been some agreement within DOD as to the management and funding responsibilities among the five partners? You know, you have created a reasonable case here for 20-percent sharing among each, and I guess that is what NASA is doing. Is that the rough pattern that you are——

Dr. DUNCAN. At this stage of the game, that is the rough pattern of how the funding is arrived at. As we progress further down, and what we learn and what we do in phase 2 is very important, we are going to be able to better ascertain the right level of participation of each of the partners based upon the end application.

Much like the line of questions that Mr. Mineta asked about human factors, we have to get into it until we find out where it is leading us, where the problems are and where it is leading us in its applications. Then, the detailed funding breakout and participation will fall from that.

Mr. BROWN. You anticipate the possibility, then, that there would be some shifting in the relative participation, both in fund-

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ing and management, by the various partners over time as it becomes more clear as to where the main emphasis is going to be?

Dr. DUNCAN. I would anticipate. We have projected ahead, obviously, a few years as to what we think would be the case in our planning among all the agencies involved, but it is an R&D program. It is not a program to develop a specific operational vehicle at this time. It is a high risk R&D program.

Mr. BROWN. But when it gets to the point where you develop a specific vehicle, if it is a successor to the shuttle, then NASA becomes a key player.

Dr. DUNCAN. Yes, sir.

Mr. BROWN. If it is an Air Force fighter plane of some type, then the Air Force becomes key.

Dr. DUNCAN. Yes, sir.

Mr. BROWN. If it is a transport to move cargo up for an SDI, it is an SDI type thing.

Dr. DUNCAN. Yes, sir.

Mr. BROWN. All right. We can see that.

Now, Dr. Colladay mentioned that you are in the final stages of reaching a memorandum of understanding with NASA. Would you comment on how you perceive the progress being made in achieving that and whether it appears to satisfy all of the needs of the parties in an equitable fashion?

Dr. DUNCAN. Yes, Mr. Chairman. I will comment on it. The press release that I referred to was a joint NASA-DOD press release. We have been talking about how to organize and the levels of responsibilities to best utilize all of the resources of all of the parties involved.

We are at somewhat of a detailed level of discussion about the organization of the joint program office which is at Wright Patterson Air Force Base. Mr. Williams is the program manager for the program and is located here in Washington.

There will be heavy NASA participation in that joint program office. The technological phases of the program involve NASA leadership and a large amount of NASA resources and facilities. The details of this are being discussed. I believe we are getting closer and closer to a reconciliation of how best to do this.

It is a matter of trying to determine how to bring together a number of different organizations who have other missions too besides this particular mission to best utilize the strengths that they can bring to bear on it, and this naturally leads to debate and not total agreement at times and not total disagreement.

Mr. BROWN. Well, you are going to have a lot of debate within the executive branch over management and priorities and so forth, but we are going to have a lot of debate in the Congress also.

Dr. DUNCAN. Yes, sir.

Mr. BROWN. The weak points in this program are going to be—or the points of contention, I should say—there is going to be a lot of argument about whether we need to go back and visit supersonic transports again in order to get from Washington to Tokyo in 2 hours. There is a lot of question about whether that is commercially necessary or viable, and we have to make the case for it.

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I don't think the Defense Department is going to make the case. I am not sure who is going to make the case for that, but it is going to have to be made.

There is also a controversy point in the role of this technology in terms of its utilization by the SDI Program just because SDI is controversial.

The really optimal situation would be to get the Congress to agree on the high degree of importance in developing the technology base for whatever utilization it might have, but that is difficult to get the Congress to agree on because they don't understand too much about the importance of developing technology base, or they may say why doesn't the airframe industry do it or something like that.

So, we need to be prepared to deal with that, and the Congress may need to restructure its own capabilities a little bit to look at programs which cut across both civilian and military applications in some sort of a balanced way, and we don't have that capability really.

Mr. Packard.

Mr. PACKARD. Thank you, Mr. Chairman.

Mr. Duncan, you stated in your testimony that there is significant risk, technical risk. What, in your opinion, is perhaps the most critical part of that technical risk? Where is the long pole in the tent?

Dr. DUNCAN. Perhaps different people would give a different answer to that, Mr. Packard, but my opinion is the propulsion development.

Mr. PACKARD. Aren't we further along in that area, though, than we are in the other parts?

Dr. DUNCAN. Yes. We have done a lot of work in that area, and when I say there is high technical risk, we wouldn't be suggesting that we go ahead if we didn't think we could solve that and that the risk was worth going ahead, because we do believe that to be the case. But I would say propulsion.

But related to propulsion are materials technology, high temperature, high strength, low weight materials Underlying any system, there are enabling technologies. That arena is the one that I would say is the most important, and during the first phase, we intend to build engines and test them.

Mr. PACKARD. If in the testing of those high risk areas, particularly the propulsion area, you find that technologically we do fall short, we simply are not able to accomplish what our initial goals were, what kind of compromises would be necessary to still reach our objectives or would we have to compromise our objectives and our goals and establish new goals?

Dr. DUNCAN. It is hard for me to answer that one, Mr. Packard. In any complex program, as any complex R&D program—I personally was involved in the Apollo Program all the way through it during the sixties—there were many points of time where an avenue closed and you had to search very hard for another avenue to proceed. Generally, we find another avenue, particularly if we have a strong commitment to succeed we find another avenue. That is the nature of a high risk R&D program.

Apollo was a high risk program.

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Mr. PACKARD. With that explanation, then, I assume that you start with a concept and then try to develop a preferred technology to meet that concept.

Dr. DUNCAN. Yes.

Mr. PACKARD. And the space plane has emerged as the preferred technology to accomplish the goals that we are seeking.

Dr. DUNCAN. Yes.

Mr. PACKARD. In reaching that——

Dr. DUNCAN. May I——

Mr. PACKARD. Well, I will let you answer it, but maybe finishing the question might help you. In reaching that, were there technologies or other procedures considered other than the space plane?

Dr. DUNCAN. What we are asking for, Mr. Packard, is not a specific vehicle but a research vehicle. We are asking for a technology development program that will lead to one or more research vehicles. The final aerospace plane will be, in all probability a far cry different in configuration from the research vehicle. That has been the history of research vehicles. It could be a whole family of operational vehicles, some military and some civil, that use the basic technology that was developed in that research vehicle program.

To emphasize the R&D nature of the program, we are talking about an opportunity to go ahead and build research vehicles if, in fact, we are successful in phase 2 which is the phase that will strive to solve those key technological problems that we see at this time.

Mr. PACKARD. And are you saying then that in looking at a family of vehicles we may find a requirement to make that family a progressive family to reach our ultimate objectives?

Dr. DUNCAN. Yes. One of the things we argued about internally, for example, early in the phase, earlier in the program was should we set single stage to orbit as an objective or should we agree upon some lower level of velocity for the system.

Mr. PACKARD. So, a single stage to orbit objective could be a part of the process of reaching our own objective.

Dr. DUNCAN. Yes, it could be. At this point in time, we would like to keep that as an objective at this point in time that we are striving for.

Mr. PACKARD. I see. Are you confident that we can still reach and meet our goal and our objective on schedule by the late—I think I have heard the date—1991? Are we on target now and do you see a slippage of that?

Dr. DUNCAN. We set April 7 as the date to release our contracts, so we are on target.

Mr. PACKARD. You say you are on target on that.

Dr. DUNCAN. Yes, we are on target. To talk about a specific date in the 1990's that we would be flying would be presumptuous on my part. I think if we have a commitment by the DOD and by NASA and by the Congress, we can do it early in the 1990's and we can have operational vehicles by the turn of the century. Unless we have that commitment by all of us, all of the parties and all of us here, it won't happen. It is a long-term commitment.

Mr. PACKARD. And the initial budget projections were in the area of $600 million through stage 2.

Dr. DUNCAN. Yes, sir.

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Mr. PACKARD. And $3 billion for stage 3.

Dr. DUNCAN. At this time, $3 billion through the flight——

Mr. PACKARD. You have seen no reason to adjust those projections?

Dr. DUNCAN. No, sir.

Mr. PACKARD. I have no further questions, Mr. Chairman. I think we have a vote call.

Mr. BROWN. Yes.

Dr. Duncan, there are a few other questions we want to ask you, but in the interests of time, I am going to ask if you would respond in writing to a few additional questions.

Dr. DUNCAN. I would be delighted, Mr. Chairman.

Mr. BROWN. We will excuse you at this time.

[Answers to some additional questions asked of Dr. Duncan plus his prepared statement follow:]

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QUESTIONS SUBMITTED BY
HOUSE TRANSPORTATION, AVIATION AND MATERIALS SUBCOMMITTEE

1. QUESTION - Please describe the distribution of the $212M FY87 budget for the NASP.

ANSWER - Our current plan anticipates distributing the FY87 funds among five major categories of efforts:

Propulsion	$112M
Airframe	$ 40M
Technology Maturation	$ 54M
Program Support	$ 5M
Application Studies	$ 1M
TOTAL	$212M

We are currently finalizing the level and distribution of the Technology Maturation funds by effort and agency and I can assure you that full use will be made of NASA's outstanding personnel and facilities.

2. QUESTION - How will the funds NASA has requested for FY87 be used and how will NASA benefit from their financial contribution to the program?

ANSWER - The major Airframe and Propulsion contracts will absorb the majority of program funds. Another large increment of dollars will be used to fund the work in the Technology Maturation area as well as residual tasks in the Airframe and Propulsion areas and for Program Support and Application Studies.

The benefit to NASA will be the same benefit which accrues to all of the participating agencies. We will all share in the knowledge and experience gained from a much needed research program which none of the five agencies could individually afford to undertake. More specifically, NASA will be a full partner in all aspects of the NASP Program. NASA will have a Deputy Program Manager assigned to both the Washington, D.C. and Dayton, Ohio program offices directly involved with management of all government and contracted efforts.

3. QUESTION - What is the status of the joint DoD/NASA MOU?

ANSWER - All of the substantive issues among the program participants have been resolved and we expect signature on the final MOU in the near future.

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4. QUESTION - Would you describe the purpose of the proposed Engine Test Facility and also any planned use of the Langley 8-foot High Temperature Tunnel by the program?

ANSWER - Within the United States and the rest of the free world, there are no facilities in which engine modules of the type envisioned for the NASP can be fully tested. Current facilities have unacceptable limits in terms of size, operating environments, test time duration and instrumentation. The Engine Test Facilities envisioned for the NASP program will be of sufficient size to allow sustained operation of full size NASP engine prototypes in a realistic operating environment at altitudes up to 110,000 feet, speeds to Mach 8, and stagnation enthalpies of 1329 Btu/lb and at sufficiently broad angles of attack to validate our computer simulations. The Langley 8-ft. High Temperature Tunnel will be used by the government and industry initially for aerothermal testing of large components of structural concepts for the airframe and engine - both cooled and uncooled. Following the modifications to the facility, it should make a valuable contribution to Phase 3 of the program by verifying single and multi-module scramjet performance from Mach 4 to 7 and would also continue to be used for aerothermostructural testing.

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DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

NATIONAL AERO-SPACE PLANE PROGRAM

STATEMENT

BY

DR. ROBERT C. DUNCAN

DIRECTOR

BEFORE THE SUBCOMMITTEE ON

TRANSPORTATION, AVIATION AND MATERIALS

COMMITTEE ON SCIENCE AND TECHNOLOGY

UNITED STATES HOUSE OF REPRESENTATIVES

9 APRIL 1986

APPROVED FOR PUBLIC RELEASE
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Mr. Chairman, members of the committee, and staff, it is a pleasure for me to appear before this subcommittee to discuss the Defense Advanced Research Projects Agency's participation in the National Aerospace Plane Program (NASP). This is a joint DoD/NASA research program which could lead to an entirely new family of aerospace vehicles. Conceptually, a future Aerospace Plane would be able to operate as an airplane at hypersonic velocities (4000 to 8000 miles per hour) in the upper atmosphere, or as a space launch vehicle capable of accelerating directly into orbit.

BACKGROUND

In 1982, the first phase of the current program began with DARPA's investigations of scramjet missiles for application to the Navy Outer Air Battle problem. DARPA also began addressing other applications of scramjet technologies and, in particular, the possibility of a hydrogen fueled vehicle. A series of analyses were performed to determine the maximum speed potential of scramjets. These analyses were iterated throughout 1983, eventually revealing the potential for a single stage to orbit (Mach 25) vehicle. Late in 1983, a group of government and industry specialists, including NASA personnel, was convened to examine the concept and to address the question of 'show-stoppers'. NASA expertise and participation were requested due to their future space transportation systems needs and the involvement of the Langley Research Center in the area of hydrogen fueled scramjets and Mach 6-12 vehicle concepts. The outcome of the two-day meeting was the preparation of an initial proposal for DARPA support of critical technologies.

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In April through June 1984, DARPA committed $6 million to continue studies of the concept. A 'government technical team' was formed and the Air Force Aeronautical Systems Division agreed to act as contract agent. The government team at this point consisted of three members from NASA Langley, one Navy and three Air Force. Due to the promising initial results produced by the contractor efforts, industry was again approached and in the fall of 1984, airframe/engine companies established small technical teams to evaluate the government's notional design. These efforts were initially unfunded. In March of 1985, a major three-day DARPA review was conducted with all government team members and industry. As a result of this review several additional small contracts were awarded.

The objective of these efforts was to assess the status of hypersonic air breathing propulsion, computational fluid dynamics, and long life, high temperature materials and structures. Based upon this work the consensus was reached that an aerospace plane might be possible. Greater knowledge of supersonic combustion phenomena, developments in high strength, lightweight materials, and the availability of supercomputers for engine/airframe design and integration are further examples of recent technological advances that support this consensus.

THE PROGRAM

Based upon the status of these critical technologies, DARPA, NASA, the Air Force, the Navy and the Strategic Defense Initiative Organization have joined forces to formulate and begin work on the National Aerospace Plane Program.

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The program is of mutual interest because of its potential to produce a hypersonic, global flight vehicle or a second generation space transportation system. It would be of major importance if it can significantly reduce payload to orbit transportation costs for both NASA and DoD. The dramatically reduced transit times on longhaul airplane routes might also have significant economic benefit, particularly on trans-pacific flights. In Air Force Systems Command's Project Forecast II, we have just begun to explore the aerospace plane's military potential.

The concept centers on a liquid hydrogen-powered aero-space craft capable of horizontal takeoff and landing. The technology development phase or Phase II, which began this year, consists of maturation of key technologies and development of propulsion modules and airframe designs needed for an experimental flight research vehicle. Engine modules will be built and tested up to approximately Mach 8, the current practical limit of wind tunnels for engine tests. An experimental aircraft, or X-vehicle, will be designed to explore propulsion performance above Mach 8, while structures and materials needed to fabricate such a vehicle will be developed and tested. All program participants and others familiar with the program understand and agree that there is a significant degree of technical risk.

This Phase II technology development program will culminate in a design for a NASP demonstrator which will validate the program goals; evaluate technology advances; fabricate and test critical hardware; and develop system components. During Phase III, the X-vehicle will be built and tested. The results of the NASP program will provide the civil industry,

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the Department of Defense and NASA, with an effective aerospace plane configuration based on technology sufficiently mature for development of operational systems.

While DARPA will lead the joint DoD-NASA technology effort for Phase II, the Air Force has been assigned overall DoD responsibility for the NASP research program and for Phase III. An internal DoD Memorandum of Agreement is currently being coordinated among the DoD participants, and we are working with NASA on a DoD-NASA Memorandum of Understanding concerning direction for this important program. Program offices for both DARPA and the Air Force will be staffed with Navy, Air Force, and NASA personnel.

There is approximately an 80%/20% funding split between DoD and NASA. The combined budgets of the DoD and NASA for the period through the end of FY 88 total about $600 million. Through Phase III, the current estimate is approximately $3 billion.

THE NASP

What might such an aero-space vehicle look like? This model is representative of several design concepts.

1. Highly integrated engine and aircraft structure whereby the aircraft fuselage forebody is an integral part of the engine inlets and the aircraft fuselage afterbody is an integral part of the engine nozzles

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2. Highly swept wing

3. High temperature metallic structure designed for many flights

4. Cooling of hot areas of nose and engine with heat pipes or fluid coolants

5. Large, highly streamlined fuselage with integral fuel tank

6. Multiple engines with multiple inlets and exhaust nozzles

We are currently in source selection for the major contracts for the Phase II efforts. The Phase II contracts have three primary objectives.

1. Definition of a NASP configuration which meets the program performance goals. The design shall be for a fully integrated configuration including cost, schedule, estimated risk, ground demonstration plan, and preliminary air vehicle specifications. The cost and performance estimates must be realistic and reproducible.

2. Design, fabrication, and testing of selected NASP subsystems/components.

3. Development of a risk assessment for technology development, cost and schedule.

The preferred research vehicle preliminary specification will be the primary product of Phase II. The specification and engine and other test data will be the primary technical inputs used to form the basis of Phase III of the NASP program. Phase III is envisioned to be a separate, competitive effort.

This concludes my formal statement. I am prepared to answer questions which you may have concerning the NASP or its applications.
Thank you.

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Mr. BROWN. We will go vote and when we return, we will hear from the two chairmen of the advisory committees, the advisory committee to this committee and the representative of the American Institute of Aeronautics and Astronautics. We think we will be able to keep to our schedule of completing the hearing by 1 o'clock if everybody has patience. We will take a brief recess to vote.

[Recess.]

Mr. BROWN. The subcommittee will come to order.

Gentlemen, if you have no objections, we will go right ahead and try to complete our record this morning. I very much appreciate your being here to assist us on this important question. I noted that Dr. Colladay made a number of references to the extensive advisory committee apparatus that the agency has, and I want the record to show clearly that in seeking our own advisory apparatus which you represent, Mr. Album, we are not trying to compete with NASA.

We are trying to bring to bear a second opinion, I guess you might say, on some of these issues or to highlight the areas in which there needs to be special attention devoted to policy issues. We do that for the purpose of improving the program, not trying to in any fashion slow it down or throw roadblocks in the way of it. Dr. McCormick, we obviously value the input of important national organizations such as you represent, because it does to some degree make us less a captive of the executive branch. We still value our independence from the executive branch where we can get it.

So, you may proceed, Mr. Album, with your statement.

STATEMENT OF H. HARVEY ALBUM, CHAIRMAN, CONGRESSIONAL AERONAUTICAL ADVISORY COMMITTEE, U.S. CONGRESS; ACCOMPANIED BY DR. BARNES W. McCORMICK

Mr. ALBUM. Mr. Chairman, the Congressional Aeronautical Advisory Committee conducted a detailed review of the NASA submitted budget for aeronautics for fiscal year 1987 and the related programs. We spent quite a bit of time doing that.

A summary of our findings is contained in a preliminary draft copy of our report which I believe all the members of the subcommittee have available to them. We completed our review just 2½ weeks ago, and, therefore, the finished report is not available here today. I hope to have that available for you next week in final form. However, the findings are complete, and I will be able to address all of those in any of your questions here today that are within the bounds of the issues that the committee considered.

First of all, let me just give a summary of our general findings. I won't try to go through all the individual programs with you and will leave that to questions.

Mr. BROWN. Well, the full content of your statement will appear in the record at this point, as will the final report be made a part of the record.

Mr. ALBUM. Yes, sir.

The general findings are these: We believe that the level of support and emphasis on aeronautics in NASA is not commensurate with the major challenges facing this Nation in aeronautics. Aeronautical research and technology is only 9 percent of the total

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NASA budget which is about $7.7 billion. In real terms, the NASA aeronautics budget has been roughly constant for the last 5 years. There are some ups and downs there, but it is about constant, taking into account the effects of inflation. This level is lower than in any year in the decade that preceded it. So we are dealing with a very constrained budget. Some of the questions that were raised here today in terms of the level of support for various programs reflect that.

Our review of the detailed programs does indicate that the level of activity is below that needed in many areas, and NASA could be criticized for not conducting work in those areas. But, I don't believe they could be criticized and, at the same time, say "keep the budget [1] just as it is.

We conducted a critical review of this budget, and we also did it from the standpoint of trying to keep from recommending any net increases above the submitted level. We did this, sir, recognizing as well the enormous pressures on the Government this year in regard to the budget.

However, I would not like to have our recommendations taken as being recommendations to keep the budget the same where, in particular areas, the Congress may find the need to increase the budget.

The Congressional Aeronautical Advisory Committee recommends the Congress accept the submitted fiscal year 1987 aeronautics budget without revision. I say that within the previous context that if you want to add money, I think there would be a lot of applause from members of our committee.

Now, we do recommend some very minor augmentations amounting to about $1.5 million for important programs, and they are really meant, sir, to be augmentations. In the event that the budget could not be augmented by that amount, we would recommend that you not make those adjustments. They should not be realignments within the budget.

So, we strongly support the budget this year. Now, one might question why, with all this work and 12-hour days and item-per-item and dollar-for-dollar reviews, did all that come down to saying we support this budget? I will have to explain that.

Last year, we recommended changes in direction and alterations in the budget amounting to about $36 million. There were six program increases amounting to $20.2 million and four program decreases amounting to $16.1 million. We recommended cancelling three facilities related to basic R&T programs that were projected to cost over $300 million for the resulting facilities that would have come at the end of them.

NASA has implemented almost all of our recommendations in the fiscal year 1987 submitted budget. Furthermore, in reviewing their plans in almost all of these areas, they indicated that the trends that we recommended would be continued in the future and that these would be the first steps.

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[1] The aeronautics budget.

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Therefore, after a careful review of the detailed programs, we didn't have any reason left to criticize the budget, and I hope my testimony today is not too boring in that regard.

We have some concerns which are long-term concerns that need to be addressed, which I will discuss, but they cannot be addressed within the context of the current budget.

In rating NASA's programs, we would rate 8 percent of them as being extremely important. In the sheets that you have, incidentally, on all the programs in the lower portion gives the rating scales. The budget sheets that we have developed give both dollar recommendations and how we rate the individual programs. So, 8 percent of them are extremely important, 26 percent we rate as very important, 57 percent as important, 6 percent as worth, and 2 percent as borderline. Now, the division between these categories is, of course, very highly subject to interpretation, and I wouldn't worry about the boundaries between any two categories. But in general I can say that our ratings this year are considerably higher than last year. The top two categories increased by 15 percent. There was a corresponding decrease by that amount in the bottom two categories. We consider this a good, well-balanced set of programs and related budget allocations within the given budget level.

Now, we have some long-term concerns which I referred to earlier that I would like to express. Some of these concerns we mentioned last year. The first and most important is, of course, the one I already mentioned, namely, the lack of emphasis in NASA in aeronautics in its budget, in its organization, and in the objectives and stated goals of the agency.

The second concern has to do with what one might call generic R&T. Here there is some confusion of terms.[1] Aeronautical R&D can be divided into a spectrum that can begin at the very fundamental levels which we call basic research in which you are looking at fundamental laws of physics and nature, such as molecules and what they do, the natures of materials, and so forth.

From there, we move into a phase of R&D which is more directed which we can call applied research where we are trying to solve specific problems. It becomes less esoteric and somewhat more intense in terms of focusing on the nature of those problems.

The next level can be called technology. The earliest portion of that is generic where you are working on components and such things. Then you move into systems technology, which may include demonstrations, and the next level beyond that is development.

The portion of the phase that we are concerned about is the earliest phase from basic research through the fundamental technology and component work. We believe that NASA has a very high orientation toward doing that kind of work. The unfortunate thing about it, and I think you referred to this earlier in regard to technology for the aerospace plane, is that it is very difficult to describe the importance of this kind of work to people who are not in the business. It is difficult to describe it to laymen. As a result, there is a tendency to focus on the more applied, the more visible type of work.

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[1] There can be and often is some confusion in what is meant by the terms applied to the steps in the R&D process.

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But, sir, out of this basic work, out of this work by maybe two or three people and maybe $150,000 or $200,000 worth of support comes the enormous innovations that make big differences in aviation. It begins at that very early stage.

The bigger programs we have in the NASA aeronautics program, the more encroachment there is on these basic seed R&T programs, often done by very brilliant people; the more that work is wiped out.

If we looked at a budget, let's say, and we were back 50 years ago and we looked at the work of Einstein, one man sitting there with a paper and pencil and a brain, how important would we look at that if that were being reviewed here today? It is enormously important, and we don't want to wipe out that early phase. It proves important later.

The next thing we are concerned about is the erosion of original R&T work due to a very expensive operational cost for facilities. This is a difficult problem for NASA. When I say we are concerned about it, I don't mean to say that they are doing a terrible job. What I mean to say is that the situation exists that the operational costs for maintenance and everything are growing, and that the R&T budget as a result is becoming compressed.

At the same time, NASA has a need to upgrade and repair its extensive facilities. We are particularly concerned about the wind tunnels which are enormously important. In that regard, we have a particular important facility that we recommend be upgraded as soon as possible, and that is the 12-foot tunnel. It is the largest high angle of attack tunnel in the country for good simulation of high lift and aircraft at high angles of attack for spin stall and so forth. It needs to be repaired. They need to get the pressure back up and the tunnel should be upgraded for larger productivity.

The final concern that we have has to do with NASA's budgeting in itself. We noticed a substantial improvement in the way in which they do their budgeting this year, simply how they budget their programs. It seems like the budget changes every year, and we struggled very much trying to understand, both last year and this year, how they do their budgeting. We were surprised to see that many people in NASA also struggle with how they do their budgeting.

Probably the biggest problem is how they allocate the cost for facilities, an enormous part of the budget. In some cases, it is allocated to the projects. In some cases, it is allocated to a project just for the facilities. In other cases, it is allocated in both places. So, when you look at an amount of work for any particular project, you are not really sure how much of that goes for original R&T and whether it includes the proper amount of facilities costs associated with that. When you look at the facilities, you are not sure what those facilities are really costing you. I think in NASA's own budgeting, they probably can agglomerate the facilities costs. They could do it either way, but whichever way they do it, I recommend that it be done in a very consistent fashion. As I say, I think the budgeting this year has improved quite a bit over last year's.

The final item in that same regard is we did not—and I have to make this point clear—in evaluating the NASA programs, we did not have manpower figures available to us. The NASA budget for

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manpower which is called research and program management is more than half the budget, roughly. It is important to know how much emphasis, in terms of NASA people, is actually being included in these various areas.

In conclusion, may I say, Mr. Chairman, that we strongly endorse the NASA aeronautics budget submitted for fiscal year 1987. The committee is pleased with the implied realignments of efforts, with the adjustments made in the budget, and we hope that you will act favorably on this budget without changes, except for small augmentations perhaps that we recommended.

Finally, I would like to step outside the issue of the aeronautics budget and address the national aerospace plane just for one moment. Our committee recommends that the national aerospace plane be addressed on its own individual merits. This program is substantially different than all of the other work going on currently within NASA, that is the work toward commercial transports, the work that we heard discussed with regard to human factors work, the helicopter, general aviation work, the high performance military type aircraft work and so forth. It is different than all of those things.

If this item of $45 million is included within the aeronautics budget, that would amount to 16 percent of the aeronautical R&D contract budget. Including the hypersonics work already in that budget which is being oriented toward the aerospace plane, it would amount to 21 percent in total of the aeronautical R&D budget. If that amount is included within the budget, I think we can forget about many of the advances [1] that we are looking for within an already tight budget. We can forget about structures, improvements for general aviation aircraft, for helicopters. I can only guess where they are going to apply the cuts, but I have almost a nightmare in terms of thinking what the net effect would be on those programs that we evaluated. So, we hope that you will address the national aerospace plane as an important project within its own context.

Now, our committee did not evaluate the National Aerospace Plane, and I would like to explain why. We did not feel that we had enough information on this program and its relationship to the military program to reach a judgment. That is the first point. We had a 1-hour briefing on it. Much of the information associated with this program is classified, and a good portion of our committee is not cleared for that. But the most important factor is that many of the members of the committee, those that would be in a position to give expert advice on this project, belong to organizations which are bidding on the Air Force's program.[2] Under the rules of conduct of our committee, they would not be able to address this program. So, I regret that we are not able to give you advice this year on the program.

That concludes my statement, sir.

Mr. BROWN. Thank you, Mr. Album.

Dr. McCormick, you have been serving as vice chairman of the committee?

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[1] Technical advances.

[2] Air Force contracts for a portion of the National Aerospace Plan.

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Dr. McCORMICK. Yes, sir. That is correct.

Mr. BROWN. And you come from an academic perspective. Do you have anything further that you would like to add or comment on with regard to the statement?

Dr. McCORMICK. I think I could only second what Mr. Album has said. I think his concise presentation here pretty well summarized the feeling of the committee and the conclusions that we came to this year.

I would like to emphasize the fact that we were—at least, I personally, and I think I speak for the other members of the committee—were rather gratified to see the realignment of NASA's budget which did reflect some of the recommendations that we made last year.

I also share his concern about the long-term upgrading of NASA facilities. It is not a very glamorous aspect of where we are putting our money but a very important one. There is a lot of excellent unique wind tunnels and other test facilities out there which over the years, I think, have simply become run down and need to be updated and modernized and instrumentation.

I also think that very generally looking at the budget, as he said, the aeronautics part of NASA's effort appears to have gone down hill over the years. I think it would be nice if we had a little more overall support in the area of aeronautics. It is very important in maintaining our competitive position in the world with regard to commercial subsonic transports, helicopters, and engines, most other areas.

Other than that, I guess we have been rather happy with what we saw this year.

Mr. BROWN. Well, the committee isn't disappointed that you came to those conclusions. It doesn't necessarily—the situation that we are in here is one which is not too favorable to large scale budget adjustments, particularly when we see a program that is reasonably well balanced. What we needed was confirmation as to whether or not we had that kind of a program. I think I can speak for the committee in saying we share your views or your reaction to the changes that NASA has made with regard to it.

Of course, we have recognized the need for upgrading facilities and equipment. As you well know, this is not a problem just with NASA. This is a problem with the university research community also which we are trying to address in some reasonable way.

Dr. McCORMICK. I think you can see from our last year's action that we are not in the business of rubber stamping what NASA recommends.

Mr. BROWN. Correct.

Mr. Packard, do you have any questions at this point?

Mr. PACKARD. Thank you, Mr. Chairman.

Mr. Album, what is the CAAC's vision and strategy for the future of aeronautics and overall was this long-term strategy used in developing a framework for assessing the merits of the individual NASA programs, or was some other method used to determine the relative value and worth of different programs?

Mr. ALBUM. Mr. Packard, the members of our committee are all leaders in aeronautics covering every segment of aeronautics from air transportation through to military aircraft and high perform-

ance aircraft. We spend our daily lives struggling with these issues in our own businesses in our own companies.

Basically, the committee makes its judgment based upon what it thinks are the most important objectives for these various sectors. The discussions revolve around that. Usually, NASA makes a point of what it considers to be the objectives, and in our deliberations, as we deal with each sector of the budget, usually people who are in that sector, for example, airlines, will stand up and say the most important thing to us is maintenance, safety, economy, and they will make a very good case for why that particular thing should be pursued. Now, they have to convince the others, because we require a two-thirds majority vote, and there is no group that it is more than 20 percent of the group. When they do convince them that that is in the national interest, they get the vote. We use secret direct voting to come up with an answer.

I don't believe that the committee as a whole has gone through a list of national priorities. We have some of these available to us, for example, the national goals. I don't think that the members of the committee necessarily subscribe to every goal that anybody gives them, but they make a good case as to why particular things should be pursued relative to their sectors.

Mr. PACKARD. So, if there is a general vision or policy, overall policy or vision of the future, it would be simply an implied. You don't have any specific policy guidelines that you can come up with that is a conglomerate of your different representation.

Mr. ALBUM. There is no individual policy, but let me give you an example of what I mean.

Take the case of high speed aircraft. There are enormous challenges ahead of us in that particular area. I think you mentioned, Mr. Brown, in regard to the supersonic transports. Now, there are some really serious concerns on the part of our airline members as to whether this is economically viable or not. The transport manufacturers on our committee are also concerned about whether it is viable or not, because, for them, they have to sell products. The other members of the committee recognize that a lot of the research associated with it will apply, for example, to fighter aircraft.

So, the point was made that when we addressed the studies that NASA is planning for this year on the supersonic transport that it is really important to find out about the economic viability of it before we launch off into a program, as was stated earlier by Dr. Colladay. And they got the vote to say, yes, it is the right thing to do. We ought to do these studies and that is an important part of the NASA budget. We shouldn't take any money away from it.

So, the prevailing thought is the national goals and what is in the national interest. And the people who are involved are in a position, I believe, to make those kinds of judgments with regard to priorities.

Mr. PACKARD. Do you think those priorities are any different or substantially different from your advisory committee's with that of NASA?

Mr. ALBUM. I would say not based on the budget, as we saw it, and the way they tried to balance the various things in the budget. They had some very difficult decisions to make, like those associated with the prop fan program and decreases there and so forth. We

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struggled with those same things, and questioned if they are they doing the right thing.I would say that most of our priorities seem to be fairly well aligned with theirs. They are responsive to their users, and their users of their output are the Government agencies, industry, and the people of the United States. I think when they know what the objectives are, they have tended to be fairly responsive.[1] That isn't to say we aren't going to differ with them sometimes, but they try to be responsive.

Mr. PACKARD. I think that the record shows that there is not that much difference. I suppose if there were a difference, it would be reflected in recommendations.

Mr. ALBUM. Yes. Let me refer to an earlier statement made by Congressman Brown regarding NASA's advisory committees. We have discussed this. We asked NASA what they plan for their advisory committees. Their advisory committees are extremely important, because they get in on the front end of the process. I hope they meet fairly regularly and work in smaller groups directly with the people involved. Through their advisory committees, they are able to provide the generation of programs.

We are kind of the safety net. We are the last vestige. We act on—we don't act; you act—but we advise you on a particular budget for a particular year. We try to give some advice on the long-term trends and needs. But NASA's advisory committees and their interactions are a very important part of the process, and we hope that they continue strong and vibrant as they have been.

Mr. PACKARD. One of the problems and concerns could emerge that we have an advisory committee, they have their advisory committees, and where there may be significant differences in the advice given, then obviously the dilemma is what direction should we go. Do you see that as a built-in problem of the system that we now have?

Mr. ALBUM. I think the establishment of this advisory committee, recognizing that being the chairman I am going to be somewhat prejudiced, but I think the establishment of this advisory committee has provided a means of improved communication to the Congress which is our sole goal. The fact that it was reflected in NASA's budget that NASA chose to take that advice is very heartwarming, but we are here for your purposes, and if we do not serve those purposes, then I would say that we probably shouldn't have one.[2]

Mr. PACKARD. Have there been some national issues and concerns that have emerged from your committees in all of their reviews and, if so, what are some of them and what do you recommend that the Congress do about these issues and concerns?

Mr. ALBUM. Well, there is always the difficulty of the balance between what you might view as being military programs and what some of your colleagues also might view as being civil programs. There really, in most cases, is not a matter of balance involved there, because so much of the work is generically related to both sectors.

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[1] Relative to the fiscal year 1987 budget.
[2] An aeronautical advisory committee for the Congress.

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Now, let's go through some of the national issues. I think the high speed aircraft is an extremely important one. We hear much said about the strategic space defense initiative. There is a lot of talk about that in terms of ballistic missile defense. But, Mr. Chairman, the Soviet Union has 450 strategic bombers. They have submarines with cruise missiles. They have a H-bomber capable of launching a missile that has a 1,800-mile range. We cannot talk about strategic defense unless we also talk about aeronautical defense. We haven't heard very much about aeronautical defense, as an example.

I think there are issues related to air transport. We have enormous pressure on the part of competitive foreign manufacturing companies backed by governments. We are engaged in a technological competition with these companies, and they have strong government backing. There is an issue as to how far our Government should go in providing support. The traditional way in which our Government has provided support, besides military procurement which has had enormous effect on the civil aeronautics sector, is through a Government laboratory organization. It used to be the NACA and now it is the NASA. The question is, how much support in terms of fundamental research and new ideas and so forth are we going to try to generate out of NASA in order to meet that competition.

And that competition is pervasive. It applies to helicopters. It is true with commercial transports. And it is true in general aviation. Just 5 short years ago, our general aviation industry delivered 17,000 aircraft. Last year, they delivered about 250,000 aircraft. The foreign competition has eaten into that. We have had the collapse of the light aircraft market. Those World War II pilots who came back at the end of the war bought 35,000 new aircraft in 1946. They could afford to buy a light aircraft. Now, they can't afford to buy one. The market has collapsed terribly. New technology along the lines of reducing maintenance costs and so forth as needed—and NASA is working on some of those problems, particularly in their engine program, for example.

The challenges that we face and the opportunities that we have before us in aeronautics are enormous. I could spend an hour and a half here going through all of the individual ones that we have to deal with. When we deal with the budget, we grapple with those major issues, but we have not sat down and mapped out a set of national goals. If you told us to do that, we would do it.

Mr. PACKARD. How does your committee view NASA's role relative to the DOD and industry?

Mr. ALBUM. This is an important question, and it comes up frequently. I think it is a very pertinent question.

NASA plays a very unusual role. The DOD has its own laboratories, and it funds work in industry. Industry funds some of its own work. So, it is natural that the question might arise, and it has arisen, particularly in OMB, as to why do we need all this work in NASA.

From the very beginning of aviation, going back more than 70 years ago when NASA was established, the fundamental role that NASA has played is in the very early phases, the long-term, innovative research, the basic work that would be common to the indus-

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try sort of across the board and to the military. The military services tend to be more near-term. I will tell you our companies tend to be more near-term. We are very profits oriented. As a result, having that group of people, having those central facilities, incidentally, at the same time commonly providing the other sectors a source of open information, has been a great stimulus in aeronautics, and it has reflected in the products that we produce and the great aeronautical power that we have become. We are emulated in other countries in that sense.

NASA has a role that it has continuously played in terms of a team member so that it is doing certain research oriented things like experimental aircraft while the military is funding and developing those aircraft and doing their part looking at the applications part. I think this blend is very important. It is very important that NASA have these kinds of relationships with the industry where they are able to provide focus, where different parts of the industry do different parts of the problem, and NASA does certain things and then the net result to the country is an overall gain.

It is important that NASA stick with their agreements, too, in doing all these different things, and we pay attention to that when we review the budget. When they get ready to diminish portions of it, they have to pay attention to what their responsibilities are to the other partners who have already made commitments to the programs.

So, these agreements and so forth are important.

NASA is a stimulator in aeronautics. That is about how I could summarize it that way.

Mr. PACKARD. How would you characterize the small differences that exist between the CAAC and the NASA views? Are they technical differences? Are they substantial major problem issue differences?

Mr. ALBUM. I would characterize most of them as being technical differences, usually very specific technical differences.[1] The second kind of difference that we run into has to do with the relative importance—because you can find many things that are important—the relative importance of things to the users. Our committee, I think, by its background and nature, represents the users.

Mr. PACKARD. And those differences—again, not very many differences——

Mr. ALBUM. Not this year, but we had a few more last year.

Mr. PACKARD. A few last year, but even then last year I think there was about a 95-percent track with one another.

Mr. ALBUM. That is right.

Mr. PACKARD. And this year even considerably less.

Mr. ALBUM. That is right.

Mr. PACKARD. Does that still justify then, in your judgment, an annual review period or committee?

Mr. ALBUM. Well, we addressed that issue last spring. It appeared that very few of our recommendations were accepted by the Congress. So, I called a meeting of an executive group of our committee to look at whether it is worth our time. You see, we have

[1] This comment relates to the fiscal year 1986 budget and, perhaps, to differences in specific programs as to their relative importance.

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put a lot of time into the committee, and individual members put in anywhere from 10 days to—our reviews were 12-hour days 2½ weeks ago, including working and traveling on weekends. So, the question was, is it worth continuing in view of the adjustments that were made from our standpoint, independent of anything else?

The overall committee, as a matter of fact, every member there said yes, it is worth continuing, because this channel of communication between the users, the people who are using NASA's results, and the Congress is important, and it will be ultimately reflected in the communications that take place with the Congress.

Mr. PACKARD. As we have heard in previous testimony, NASA has its own—and we discussed that in earlier questions—NASA has its own advisory system which is a complex and rather all-inclusive type of advisory structure. Do you believe or has your committee reviewed their Advisory Program and made any determination relative to whether industry versus DOD is adequately involved in their advisory structure?

Mr. ALBUM. We have concerns about their advisory structure in terms of how effective it is for that generation part of the process, and we asked NASA about that in our review this year. But we have not really closely looked at the system in terms of whether it really is generating programs the way it ought to.

Mr. PACKARD. So there were no recommendations made in this year's——

Mr. ALBUM. For changes there. We should take a look. It would be wise for us to take a look at some of the fundamental issues that relate to NASA in terms of interrelationships such as that.

We did visit Wright Patterson this year, and we reviewed the Air Force's aeronautical R&D programs with the idea of seeing how they interface with the NASA programs and also to make sure that NASA wasn't putting money into areas that the DOD was already funding. We found a very close relationship between programs that they were doing in terms of being complementary and so forth. So, in that sense, we did look at that.

But relative to the advisory committees, I think it is such an important area that it is probably something we ought to look at to make sure that we are getting those really good generating influences back and forth.

Incidentally, it is also valuable to the companies because, at these advisory committee meetings, there are information exchanges that are also valuable to the companies in planning their directions and which direction they are going to be going. So, it has a national benefit.

Mr. PACKARD. Your advisory committee is made up of company representatives and industry representatives. How do you ensure that there is not conflicts of interest in terms of budget recommendations that may have some either hidden or obvious impacts upon the companies that are represented on your committee?

Mr. ALBUM. That is an area that was stressed right from the beginning in the procedures that were developed for the advisory committee last year even before the committee started up. The first aspect is the selection of the individual members. The individual members are selected by a separate selection committee that is put together by your committee. There were four members on the com-

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mittee, of which I was one. One member was from a manufacturers association, that happened to be the General Aviation Manufacturers Association [GAMA]. Another members was a vice president of a company that would not be represented on our committee, but the guy has a very extensive background in military aviation. The third member was from a university, was from Stanford. So, all of the people who were to be reviewed for the committee were rated and scrupulously rated by this group.

The one question that was not asked was whether they were Republican or not, and, Mr. Chairman, I have to tell you I am a registered Republican, and I know that you are of the opposite persuasion.[1] But, that doesn't enter into any of our technical judgments.

Mr. PACKARD. I am sure that ought not to be a factor.

One last question, if I may, Mr. Chairman. Your priority assessments listed—how are those determined and what need do they fill and are they used, in your judgment, and if so, how are they used? Is it an arbitrary process that when you weigh a 72 versus a 70 or a 69 which may throw from 1 category of importance to relatively not important? How is that done where and what is its utility?

Mr. ALBUM. The priority ratings themselves are done twice. They are done once after reviewing NASA's programs, like after a review program in the morning and then you would review them in the afternoon.

I ask the committee first to list all the positives in regard to each program and then to go over all the negatives. They contribute to both sides, incidentally. That is so we don't develop a polarized position. After doing that, I take a vote of the committee, which is a secret vote done on a computer type machine. Then I see whether there is agreement in the committee. That is the first question. Can they agree on this number?

Now, you can imagine, you have these five different sectors [2] and you are picking numbers between 0 and 100. So, you would think they are going to be all over the place.[3] If they don't know enough about the program they will not agree. They are going to be all over the place if they are really competing with each other. So, the committee vote then has to be, two-thirds of the committee vote has to be within 5 points of the basic vote. For example, a 72 says you have to be 5 points either side of the 72 for two-thirds.

Mr. PACKARD. Are they given that number to vote on?

Mr. ALBUM. No.

Mr. PACKARD. Or do they pick their own numbers?

Mr. ALBUM. They pick their own number. Everybody just plugs in the machine, and sometimes it happens that you don't have a consensus and they are just all over the place.[4] So, obviously, either you are going to say we don't know about this program. We didn't have a consensus on the aerospace plane and they, in fact,

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[1] The congressional subcommittee chairman, Mr. Brown, appointed Mr. Album to chair the advisory committee.

[2] People on the advisory committee were from five different sectors of aeronautics and they were all from different organizations.

[3] In their voting, the priority numbers voted by advisory committee members will be widely scattered.

[4] The minimum required to indicate a consensus of the committee is a two-thirds majority vote.

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voted not to vote on it. They are going to be all over the place.[1] So, then, you either discuss it further until you can develop a consensus or you answer with no comment. I will give you an example. Last year, we had the Oblique Wing Program.[2] We had no consensus on that last year. This year, we had a consensus on it. There was enough information and they developed a consensus.

Now, I would say there is no difference between a 72 and a 70. In fact, we don't assign it much in the way of a difference. But there is a difference between a 70 and a 76.

Mr. PACKARD. What is the intent of the priority assessment? How is it used?

Mr. ALBUM. We take the priority assessment and first I go through and indicate all the priorities. Then we indicate whether we think there ought to be a budget change relative to that priority. First, how important the group thinks it is. Then, should there be change to the budget? These are two different determinations. Something can have a very high priority but it is adequately funded. And we reflected this in last year's advice in a number of areas.

We said computional fluid dynamics had a high priority, but that it had enough money on it. So, you have to make two separate determinations. But the first determination is how important it is or you don't know what to do about the budget. So, that is the first step.

Then we go through the second time around and look at all those areas and all those priorities and we say, in view of the priority of this relative to the other areas, it is appropriately funded, that whole area, and then are the individual programs properly funded. The ones that have a low priority you are looking at from the standpoint of decreasing the funds. Now, we had some low priority programs which we did not decrease the funds in this year's budget, and we didn't decrease the funds for very specific reasons which are stated in the tables. They had to do with other commitments and it had to do with waiting to see for certain results to come out. Last year, we gave a low priority to laminar flow control, but they didn't change the money because they wanted to see the outcome of this year's Jetstar flight test program. I sent a committee of experts down there who reviewed the results, and the priority this year went to very important from marginal once we had the results.[3] So, you use those priorities in a very deterministic way.

Mr. PACKARD. Thank you, Mr. Chairman.

Mr. BROWN. Your questions have been very good, Mr. Packard.

Mr. PACKARD. Thank you. Very lengthy, too, I know.

Mr. BROWN. The answers have been very good also.

Do you have any questions, Mr. Boehlert?

Mr. BOEHLERT. No, thank you, Mr. Chairman.

Mr. BROWN. Gentlemen, you have done an excellent job, and I am even more strongly convinced of the value of the work that you have done as a result of hearing both the description of the results and the process that you use. Your evaluation process sounds some-

[1] The voting numbers as to priorities will be widely scattered.
[2] Correction, the X-Wing Program.
[3] The advisory subcommittee visited NASA-I angley January 31, 1986.

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thing like what I used to hear referred to as a Delphi process, and editive evaluation process.

Mr. PACKARD. Mr. Chairman, may I ask one other question? I had it written on a separate sheet.

Earlier, Mr. Mineta asked Dr. Colladay why NASA has increased their human factors work in rotorcraft at the apparent expense of the commercial transport research in human factors. Would you like to comment on that briefly, Mr. Album?

Mr. ALBUM. Yes; I will. I was mentioning earlier to someone else that having endorsed the NASA program, I am put in the position of having to defend that program, which is an unusual position for us. I think the helicopter question that was asked is a very important question in the sense that it is indicative of the situation that we found when we reviewed the budget. There are a lot of areas such as the commercial transport human factors area that really need more attention to meet the challenges ahead and the difficulties.

I don't believe that from our review of the budget that you could find fault with NASA for not supporting those areas within the current budget level, because weighing all priorities across the range, it is a matter of balance. It is a matter of which good work you don't do. It is not a matter of which crummy work you leave out. It is a real problem. Now, the helicopter area versus the transport area is one; we do need much more work in the area of human factors for transports and cockpit work.

I also visited NASA's human factors group there at NASA Ames. I have to tell you, before I went there, I didn't have a very high impression of the importance of that work. Once being there, I completely changed my views entirely. I think it is a very important and vibrant group looking at some very important problems and, I might say, doing a great deal with small amounts of money.

Now, in the helicopter area itself—I am glad you asked me that question because 3 months ago, I witnessed directly a crash of two helicopters and was involved in rescue operations in San Pedro. I got kind of wet, and one person was killed. But that accident was kind of indicative of the kinds of problems you can face with helicopters. These two helicopters were landing in a very confined area, and one just plain didn't see the other with a bridge on one side and a boat on the other side.

Our helicopters are operating more and more in highly densely populated central city areas. We have executive type helicopters landing on rooftops and backyards and so forth. Those problems, including the use of helicopters for rescue in wooded areas and in mountainous areas, helicopters for evacuation, helicopters for use in agriculture where you have problems with power lines and so forth, those problems are not that different from the Army's problems of operating helicopters in and out of trees and so forth. So, that kind of research in human factors will pay off for our civil helicopters in some very important safety type issues. I think for the small amount of work and the small amount of money involved that the money is well spent. We looked at that particular item, I think, fairly closely from the same viewpoint.

Mr. PACKARD. Thank you, Mr. Chairman.

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Mr. BROWN. Thank you very much, Mr. Album, Dr. McCormick. You have been extremely helpful to us, and we appreciate it very much. We look forward to getting the complete report.

Lastly this morning, we have Dr. Norris J. Krone who is chairman of the AIAA Ad Hoc Advisory Committee on National Aeronautics. We apologize for the fact that you come in late, but somebody always to be the last one, Dr. Krone.

Dr. KRONE. Yes, sir.

Under the time constraints that we have, I will try to be as brief as possible. I have listened to most of the testimony this morning, and I will try not to overlap as much as possible.

Mr. BROWN. We will put your full statement in the record, of course, Dr. Krone.

STATEMENT OF DR. NORRIS J. KRONE, CHAIRMAN, AIAA AD HOC ADVISORY COMMITTEE ON NATIONAL AERONAUTICS, AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

Dr. KRONE. We do appreciate the opportunity to come and express our views. I am expressing the views for the American Institute of Aeronautics and Astronautics. I am the chairman of the ad hoc committee for reviewing the NASA aeronautics budget every year.

In that connection, let me say that the members of that committee are very similar to the members of the previous committee whose chairman gave testimony here. The are leaders from industry as well as Government, generally speaking, at the advanced development director level or the director of aeronautical technologies either from a company or from a division of a Government organization, and I am speaking now of DOD organizations primarily, Air Force and Navy.

Now, the last few years, we have expressed a belief that the NASA aeronautics budget has not been commensurate with maintaining total aeronautical superiority in the technical world, not that it hasn't been considerable. But relatively speaking to the future aeronautical products market, which is estimated at something like $535 billion over the next 10 years and quite a considerable amount of that is strictly air breathing transports and fighter aircraft and those sorts of things, that there should be a strengthening of that budget.

As I say, we believe in order to capture the percentage of that market that we have been used to, become accustomed to, and for maintaining the positive balance of trade in the aeronautics products world, that budget should be increased.

This year, in looking at it, we are gratified to see that there is recognition of that problem. One of the evidences of that recognition is the Office of Science and Technology's publication of the national aeronautics and R&D goals.

We support all of the goals in that document, including the subsonic, supersonic, and hypersonic goals. Particularly, we are encouraged to see the recognition that there could be legislation that would help improve the problem relative to foreign competition, incentives for private investment, incentives for greater cooperation between R&D organizations, and most specifically and importantly,

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incentives for recognizing the fact that in the procurement policy world, R&D products should be different than standard hardware products.

I think I would like to expound on that just a little bit and say that we are looking for innovation. We are looking for really brilliant ideas. We are looking for concepts that can make a difference.

In that world, when someone has one of those concepts or ideas and comes forward with it and goes to a Government organization—and now I am speaking of either NASA or the DOD—he runs up against, I can say from personal experience, a rather formidable organization and bureaucracy, if you will, and it would get into the competitive business.

Now, I submit that when someone truly comes up with an innovative and brilliant concept and tries to market it to a Government organization, when you go to the competitive business similar to what you would with a piece of hardware, it becomes a great disconnect. So, the recommendation in that policy relative to recognizing that difference, I think, is very important.

Now, the NASA budget itself we feel that the increase in the technology level is a direct investment in the future and the ability to capture that portion of the market that we have in the past.

We do recognize the fact that there has been an increase and it was taken into consideration by the committee that this is a hard budget year. With the Gramm-Rudman-Hollings, it makes it even harder, and it is $22 million that is an increase over the 1986 NASA budget along with the $45 million into the national aerospace plane is certainly a step in the right direction.

Now, we did look at the National Aerospace Plane Program, and, as a matter of fact, you, Mr. Chairman, asked us to do that. We would like to go back on that and say that we recommended last year in our testimony that there be an increase in hypersonics flight regime. We also recommended that there should be provisions for flight research vehicles to correlate analytical as well as wind tunnel results.

The National Aerospace Plane Program represents an increase or essentially a rebirth of the hypersonics flight regime research that was in full blossom between the early sixties and the mid seventies. In the mid seventies, there was a definite retardation, probably caused by a number of factors. The high fuel costs and the cancellation and lack of interest at that point of the supersonic transport were probably paramount.

At that point, there was a definite reduction in research in certain areas connected with hypersonics, and that included the hypersonics aerodynamics, scramjet propulsion, cryogenic cooling, and thermal protection, as well as the subsystem and system integration work. There was great activity just previous to approximately 1975 and 1976.

However, there were other technologies that went forward rather rapidly, structural design techniques, high temperature materials, strength materials, most importantly, avionics and flight control capabilities, and probably the most important, the advancement in computer sciences with supercomputers and the ability to solve very complex flow field equations numerically that simply couldn't be done in a closed format in a strictly analytical manner.

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For that reason, we do support the aerospace plane project because we believe those technologies have sparked the interest and the ability to be able to build a successful at least flight demonstration aircraft and it is time to do that.

So, part of our support comes from the fact that there has been a rather low level of activity in that particular regime over the last 10 years. So, we are glad to see it come along.

Now, the key technology there, we feel, is no doubt the propulsion technology. NASA has already laid the groundwork for that and, as a matter of fact, the hydrogen burning propulsion module that has been tested at NASA over the last—well, it was tested about 5 years ago and has been perfected—is in fact the basis for the Aerospace Plane Program.

Clearly demonstrated there was the fact that you must integrate the propulsion system with the vehicle design, and there is basically no other vehicle that has had that requirement.

Also the materials development, we think there is an enormous challenge there to handle the heat loads, and temperatures that you will see in one of these vehicles. That leads back also to the propulsion challenges. The space shuttle itself faces those, but only for relatively short times and not in a propulsion mode. Basically, those are faced in the space shuttle in its reentry. And they have been problems for the space shuttle.

So, the technology is not entirely here or the technology is here for handling it, but from the standpoint of practical everyday use, those technologies need further development.

We did find one clear technical issue relative to the program, and that was with regard to the data base available for the design of an experimental vehicle. In that regard, the ability to correlate the predicted analytical designs, in other words, performance value that would be predicted, with test results.

We recommend there, clearly, that there be a study made some time early in the program to clearly demonstrate how the design characteristics of the vehicle will be correlated by test. There are a number of very, very complex aspects to that design. For example, naming a few, the interaction between the vehicle and engine flow, the effects of forebody cross flow under the viscous situation that we have with the engine inlet ducts and flight control response to vehicle dynamics.

There are a lot of rather sophisticated phenomena that have to be predicted by the analytical means, and what is normally done in the supersonic and the subsonic design regime is you predict as best you can with the analytical tools, you do the wind tunnel testing that you have the money for and the availability of tunnel time for. Then you go and you run some kind of a flight test if you need it.

Here, we are talking about being able to predict and go flight test directly, although, I will say in that regard, there is no way that we are going to really be able to test on the ground this vehicle in large scale version because of the high mach numbers, the high velocities, and the altitudes that are involved here.

So, that in itself is a support for the program, because you have to build an experimental vehicle before you can really know that

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you have been able to predict the performance. But it is something that we think ought to be looked at very carefully.

As far as the application of an aerospace plane, the committee felt that the initial application would be in the military world. Applications are different than technology development. As a previous speaker mentioned, there are different levels of that technology development.

The experimental vehicle represents an advanced form of that, but from the standpoint of an application, we think the military applications are most likely the first applications, high speed reconnaissance, high speed or a different type of a strategic system, et cetera.

We think the space transportation system or a shuttle follow-on is probably right up there as next in that regard as far as a useful application. In that regard, we felt that the *Challenger* problem and the space shuttle itself, in other words, improvements in the space shuttle, should be totally decoupled from this program.

In other words, it is too early to really talk about an aerospace plane air breather one stage to orbit as being a replacement for the space shuttle. Our committee feels that we have many years that we are going to have both the commercial and military need to put the payloads into space before we are going to be able to say, with confidence, we have this capability.

We feel in that regard that this is a future capability, not a present one, in other words.

Relatively to the management, very briefly, our investigation indicated great enthusiasm among all agencies involved. Without doubt, that is true.

They all recognize the challenges. They have not signed the memoranda of understanding that essentially delineate the interfaces and the responsibilities and so forth. From personal experience, that is not always easy, but with the enthusiasm, I think there is a high likelihood that that can be accomplished in this particular case.

Back to the NASA budget just in brief, we did indicate four areas this year that we felt needed emphasis, and these are areas, I think, that are important relative to the subsonic and the supersonic goals that were stated in the OSTP policy.

Verification of computational codes ties in with the aerospace plane. The engine hot section work—we think that the turbine engine is going to be with us and the bread and butter of the commercial and military world for a long time, and the increased life and prediction of life of those is very important. Engine use, incidentally, is almost a black art. In other words, engine life predictions are very much an area where great commercial as well as military gains can be derived.

Advanced structures, large components—let me say a word about that for a second. Advanced composite materials are really terrific in their performance capabilities. You can actually design the material to meet a specific need. They have been around in some form for about 15 years now. Yet, there are still many who are a little bit nervous about the use of those materials.

The real reason is that they can be designed for specific purposes, but the manufacturing techniques that are used are not alto-

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gether to the reliability level that we have with normal metal structures. So, there is still some reluctance to use them even though they do offer great benefit.

In summary, let me say that, again, we appreciate the opportunity, and we do feel that the NASA aeronautics budget is a well-balanced budget. We do support it. We would obviously like to see increases in it if at all possible. We do support the resurgence of the hypersonics research area.

That completes my statement. I would be happy to answer any questions.

Mr. BROWN. Thank you very much, Dr. Krone. Your statement is particularly useful because of the emphasis you have given to the aerospace plane which was an area which our own advisory committee felt they were unable to adequately comment on because of a number of factors that they mentioned.

Mr. Boehlert.

Mr. BOEHLERT. No questions, Mr. Chairman.

Dr. Krone, I just want to thank you for the comprehensive statement. You answered most of the questions I had to ask you as your statement progressed. Thank you.

Mr. BROWN. He did a good job of answering the questions that we would normally ask.

In light of the time situation, Dr. Krone, I am going to defer any questions myself but ask if you would respond in writing to any questions we might generate here among the staff and the members. If you will agree to do that, we will be able to get out of here on schedule.

Dr. KRONE. Yes, sir. I would be most happy to.

Mr. BROWN. All right. Thank you very much. We look forward to continuing to work with you.

Dr. KRONE. Thank you.

Mr. BROWN. The subcommittee will be adjourned.

[Whereupon, at 1:02 p.m., the subcommittee adjourned, to reconvene subject to the call of the Chair.]

[The prepared statement of Dr. Krone follows:]

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Statement to

Subcommittee on Transportation, Aviation and Materials
Committee on Science and Technology
U.S. House of Representatives

by

Dr. Norris J. Krone, Chairman
AIAA Ad Hoc Advisory Committee on National Aeronautics

American Institute of Aeronautics and Astronautics
April 9, 1986

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NATIONAL COMMITMENT TO AERONAUTICS

For the last few years the AIAA has been expressing profound concern regarding the Government's commitment to maintaining the U.S. as the dominant country in the field of aeronautics. Although the Government resources allocated to the development of aeronautical technology have been considerable it has been our position that the resource levels allocated to NASA were not commensurate with either the enormous free world aeronautics product market of the future, estimated to be approximately $535 billion dollars over the next ten years, or to maintain a strong lead in the critical military aircraft performance arena.

This situation continues to exist; however, we are pleased that there seems to be an increasing recognition of the problem. The "National Aeronautical R&D Goals" published in March 1985 by the Office of Science and Technology Policy (OSTP) is direct evidence of this, and we wholeheartedly endorse the stated goals and the accompanying revitalization strategy. The OSTP's recommendations for amendment of the Federal contracting and regulatory policy to distinguish between hardware and R&D procurements, for encouragement of cooperative efforts in technology developments and for the passage of Federal tax legislation to encourage private investment are three actions that may partially counter the increasing direct support being given to the foreign commercial aircraft industries by their governments.

The National security is dependent on maintaining superior aerospace products; however, it should not be forgotten that the viability of the industrial base for military aerospace products is integrated to a large degree with the commercial base - they are mutually supportive. In this connection, we need to examine procurement regulations to find ways to eliminate the time required to develop and procure new weapon systems.

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The U.S. aerospace industry employs a large work force with huge total sales covering a wide variety of products including products of other industries (food, furniture, etc.), and enjoys a large favorable balance of trade in the world marketplace. There is no reason to believe the aerospace industry couldn't suffer the same fate as our ship building industry did after World War II if we don't work to maintain the technology advantage which is the key to superiority of future products, maintenance of the national security and leadership in world sales of aeronautical products. The degree of national security and the proportion of the world aeronautical products market that is captured in the future by the U.S. is directly related to the investment we make in today's aeronautical technology programs - there are tremendous dividends to be reaped in the future.

NASA FY 87 AERONAUTICS PROGRAM

General

Although the FY87 NASA aeronautics program reflects a growing recognition of the importance of aeronautical Research and Technology to the health of the country, we believe the 8.0% portion of the NASA budget devoted to aeronautical R&T is insufficient to maintain the U.S. as the dominant aeronautical country in the world. However, the $22M increase over the FY86 R&D Technology budget level plus the $45M programmed for the national aerospace plane does certainly represent a step in the right direction.

The National Aerospace (NASP)

Hypersonic Technology - Last year, hypersonic technology was one of five areas we recommended for additional emphasis. We also recommended research programs directed at flight research vehicles to verify design parameters and correlate ground based (analytical and wind tunnel) predictions. Therefore we support

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the NASP program which represents the revitalization of the hypersonic flight regime research efforts that were in full stride between 1965 and 1975. A combination of factors including high fuel prices and the loss of interest in the high speed supersonic transport caused a retardation of hypersonic research in such disciplines as aerodynamics, scramjet propulsion systems, cryogenic cooling/thermal protection systems and vehicle system/sub-systems design and integration technologies - ones that are now being revived by the NSAP program. On the other hand, there are other technologies that have a direct bearing on our ability to build a practical aerospace plane that have been advancing rapidly during the last ten years - ones that have sparked the renewed interest in hypersonic aircraft. Included in these technologies are structural design techniques, high strength/temperature material sciences, avionics and advanced automated control design methodologies, computer science hardware and software which enable us to solve complex flow field equations numerically, and techniques for handling large volumes of liquid hydrogen efficiently. We believe the technology has reached a point where the time is right to initiate actions directed at the definition of a hypersonic research vehicle.

The propulsion system is a critical key to the development of a useful aerospace plane. The Langley Research Center conducted a Hypersonics Research Engine (HRE) program that demonstrated the basic feasibility of building an engine that could operate at mach numbers greater than 5. It also led to the important conclusion that the only concept practical for a hypersonic airbreathing vehicle would require an integrated airframe/engine design. A scaled module of such a hydrogen burning propulsion unit was built and tested to Mach 7 at NASA Langley. This effort laid the foundation for the propulsion concept; and therefore, the entire vehicle concept of the current aerospace plane program.

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The ability to build a practical aerospace plane also depends heavily on reducing the structural weight of the vehicle. The enormous heat and temperature environment (both internal and external to the vehicle) presents a unique set of problems and challenges in addition to the ones normally existent for subsonic or supersonic air vehicles. Recent advances in high temperature metals and metal matrix materials, advanced carbon-carbon, advance ceramics, structural designs for hydrogen regeneratively-cooled techniques and advanced insulated cryogenic tank designs have raised the expectations of reaching a vehicle structural weight threshold that will allow practical and economic hypersonic applications. The progress made during Phase II of the aerospace plane program should allow for a reasonable assessment of structural weights based on design configuration studies and material/structural data.

One major technical issue is the establishment of an adequate data base and overall validation of the design of the experimental manned transatmospheric research vehicle since the full scale vehicle can not be ground tested through the full range of its operational flight speeds, Mach numbers and altitudes. A thorough evaluation of existing ground research facilities, their modernization and upgrading needs, the need for new ground facilities as well as possible flight research facility options must be established and the corresponding budget requirements defined. It is conceivable that if within the next two to three years sufficient progress has been made in Computational Fluid Dynamics, and if the methods are validated by realistic testing to a high degree of confidence, the need for extensive new ground and flight research facilities may not be too great. This facility evaluation is necessary in order to assure the ability to verify analytically determined design parameters associated with uncertainties such as the interaction between vehicle and engine flow fields, inlet region effects of forebody crossflow and viscous

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influences, inlet spillage flow effects with angle of attack variations, dynamic interactions between the engine operation and the vehicle motion, flight control dynamic responses to nozzle lift/thrust and pitching moment variation, etc. It is recommended that a substantial effort be conducted as soon as feasible to define the facility needs with a high level of realism.

Application - Military vehicle effectiveness is generally measured by its ability to defeat a projected enemy threat. Commercial vehicle effectiveness is almost always measured by its ability to compete economically with other vehicles that can meet the projected need. Hypersonic air breathing vehicles have the potential to meet both military and commercial requirements; however, it is likely that the military benefits in the form of a high speed reconnaissance, attack or interception aircraft will initially be shown as viable applications. Single or first stage of an advanced Space Transportation System (STS) is also a potential early use of the technology. The hypersonic transport aircraft application must meet more stringent safety and economic (total operations) constraints and is therefore considered a longer term application which will probably depend upon the experience gained from earlier military or STS applications.

Effect of the Space Shuttle Challenger - The AIAA membership shares the National grief following the loss of the Challenger and its flight crew. We are confident that when the facts are in and the analysis complete, the Shuttle program will go forward as a better and safer program. However, we believe it is important to remember that pushing the frontiers of aeronautics has always been and will continue to be accompanied with risk. As is the case for ordinary aircraft there is no such thing as 100% safety and when we are flying with vehicles designed to operate at extreme speeds, Mach numbers and

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altitudes the uncertainties are higher, the energy levels are enormous and the risks are also higher. This does not mean that we should not continuously strive towards and set as our goal 100% safety.

The nation's immediate, near and intermediate term need for a space transportation system (STS) should be totally uncoupled from the aerospace program. The space shuttle utilizes proven technology and it has completed an immense amount of testing which includes 24 successful flights. The aerospace plane is projected to be a more efficient STS; however, it must meet and overcome numerous technical challenges before it can be confidently substituted into the line up. The aerospace plane technology should be pursued as the key to our long term dominance in world aeronautics and the priority placed on it should be assigned in accordance with this goal.

Aerospace Plane Management - There is a great deal of enthusiasm among all agencies participating in the aerospace plane project. It is viewed by all as an exciting challenge; and therefore, there exists an opportunity to demonstrate unprecedented cooperation. The memoranda of agreements are currently being formulated and it is therefore too early to realistically judge how effectively the various agencies will interface or how the various agencies will divide the responsibility.

The flight vehicle planned for Phase III of the program should be based on solid technical progress made during Phase II of the program and not upon preconceived schedules. There should be no serious management problems during Phase III if the various organizations can agree on the Phase II program plan and specific requirements of the research vehicle.

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National Aeronautical Goals

The goals established by OSTP in March 1985 specified objectives in each of the three flight regimes - subsonic, supersonic and transatmospheric (hypersonic). The NASA support of the transatmospheric regime is clearly reflected in the FY87 program and as stated earlier we wholeheartedly support this increased emphasis. However, we feel very strongly that the near term goals and specifically those programs associated with increased efficiency for subsonic and supersonic aircraft are inadequate.

The technology required to reduce fuel consumption by a factor of two for subsonic aircraft is a realistic near term objective. One important key to accomplishing this would be the demonstration of practical techniques for maintaining laminar flow over the aircraft surface. Past efforts have shown the tremendous potential of laminar flow techniques; however, there is insufficient effort directed towards the development of integrating laminar flow techniques into the a practical aircraft design that includes low cost manufacturing and the reduction of day-to-day operating expenses. A flight demonstration of a practical laminar flow design is needed.

It is probable that there will be within 10 years an advanced operational transpacific supersonic transport with a range of five to six thousand miles and with ticket cost comparable with subsonic transports. A reduction from 10 to 3 or 4 hours flight time from the U.S. to the Pacific basin will open an enormous new market that we should not ignore. Also, efficient supersonic cruise has direct application to next generation military aircraft. Technologies that integrate to produce this capability include advanced material, propulsion and aerodynamic designs. NASA should increase its efforts directed at developing analytical capabilities that integrate the tools of various technology disciplines (structure, aerodynamic, etc.) into multi-diciplinary tools for producing realistic and optimized design options. Flight demonstrations to verify the new analytical capabilities are essential.

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Technology Base Programs

The national aeronautical goals cannot be met without a strong and vigorous technology base program. Therefore, we strongly recommend the strengthening of the NASA program in the areas of: (1) verification and correlation of computational aerodynamics codes, (2) engine hot section technology for increasing engine life and reducing maintenance costs, (3) advanced structures and materials (metals and composites) and (4) rotorcraft technologies.

Verification of Computational Codes - The ability to determine the characteristics and parameters of a complex flow field accurately has been greatly improved through the use of high speed computer simulation that uses numerical solution methods. Traditionally, analytical methods have been used in the initial design of air vehicle and propulsion systems but the final design has always required and has been the result of extensive wind tunnel and flight tests. With the development of advanced computational capability, significantly less hardware testing will be required; however, the computational tools are far from perfect and the code development must be accompanied by a vigorous and systematic program to provide comprehensive experimental verification and correlation of analytical predictions. Confidence in the codes can only be gained by a carefully structured verification program expanded to cover the full range of configurations and aerodynamic/thermodynamic phenomena to which the computational procedures are applied. It is important to realize that experimental verification is a vital element of the overall computational aerodynamics program, and it must receive at least equal emphasis to the development of the codes and computer facilities themselves. To do otherwise will result in less than desirable return on investment and could, if experimental verification is slighted, waste a portion of a vital national resource.

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Turbine Engine Hot Section Technology - Although great emphasis is being placed on a propulsion system for the hypersonic flight vehicle it must not be forgotten that the "bread and butter" for aircraft propulsion for many years to come will be the gas turbine engine. The subsonic and supersonic national goals are dependent upon extending the life of the engine hot section components (by a factor of two) and reducing the maintenance cost of gas turbine engines. Starting in 1981 NASA did a commendable job in implementing the Hot Section Technology (HOST) program and as a result efforts to improve the understanding of the gas turbine hot section aerothermal environment and material structural responses are presently underway through a combination of contracts, grants and NASA in-house research activities. However, considerable additional work remains to be done in order to reap the potential benefits in this important key area for improving engine performance.

HOST developed hot section life prediction methods and life extension techniques are receiving broad application in the industry. Not only are these methods being used for their original turbofan application, they also are being used in advanced military engines as well as parts of the Space Shuttle Main Engine (SSME). Even broader application of the HOST developed concepts is possible. The NASP will require development and application of life prediction methods for a large portion of the vehicle as well as the propulsion system because of the generally hostile temperature environment brought about by the heating effects of high speed flight. In addition, the techniques developed under HOST should be extended to solve hot section problems in small size engines. NASA-Lewis has managed its internal HOST program very well and integrated the industry and academia participation in an effective manner. This very effective team should be retained in future years to pursue the aforementioned expansion of their work.

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Advanced Structures and Composite Materials - The reduction of structural weight by use of advanced composite materials is potentially the most important single technology needed for meeting the national aeronautics goals in all flight regimes. Application of advanced composites to primary structures of future subsonic transport aircraft is clearly necessary to maintain the U.S. competitive position in the international market and this position may be seriously jeopardized with the abandonment of the large structures programs.

Metal matrix composite materials consist of high strength fibers such as silicon carbide or boron, imbedded in a metal matrix (aluminum, titanium, etc.). The payoff of these material is a substantial reduction in structural weight which has been verified by studies of large transport type aircraft that indicate a 35 percent reduction in structural weight when 33 percent of the structural material is metal matrix. This saving results from a complete resizing of the aircraft with lower associated engine power and reduced fuel requirements. Metal matrix materials development is being supported at a level well below that commensurate with its potential payoffs. Integrating the different materials, manufacturing techniques and maintaining structural integrity over many cycles of repeatable varying environments is the objective of these efforts.

Rotorcraft Technologies - The rotorcraft portion of this country's aerospace activity has probably been its most rapidly growing element in recent years. Capabilities of helicopters have improved very measurably and the numbers of aircraft used by both civil and military operators - approximately 40 percent of the military vehicles are rotorcraft - has grown substantially. The trend is continuing as more missions are identified and as lower operating costs bring rotorcraft within reach of more potential users.

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Last year the AIAA stressed increased emphasis on rotorcraft R&D as one of its five specific recommendations. We are pleased to see the degree to which the 1987 budget has been able to move in that direction. Specifically, a focused program and goal for reduced noise and vibration has been established; this does address two high priority needs. The NASA National Rotorcraft Noise Reduction $(NR)^2$ program has been a unique, successful example of a new kind of R&D. Four contractors are being partially supported by NASA, partially by their own IR&D, and the combined efforts of the four plus NASA's in-house effort are being coordinated by NASA Langley, with a sharing of data among all parties. This approach appears to give maximum return on the taxpayer dollars and may well be an example that should be copied in other areas of basic research.

NASA has small programs in the technical areas of handling qualities (taking advantage of new digital avionics), economical deicing of rotors (for all-weather operations), low air speed systems, improved cockpits for unburdening the pilot, and efforts to predict rotor aerodynamics. Although these programs are in the right direction they need strengthening to keep pace with the foreign competition for the expanding helocraft market.

Conclusion

The AIAA strongly supports the national aeronautical goals and the renewed interest in the hypersonic regime as indicated in the NASA FY87 program. However, we believe the support of the near term subsonic and supersonic technologies are deficient and should be strengthened.

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Dr. Norris J. Krone, Jr.

Dr. Norris J. Krone Jr. is currently the Executive Director of the University Research Foundation at the University of Maryland. Dr. Krone has been involved in aviation for nearly thirty years both as a pilot and in the aeronautical engineering and development field.

He was the Director of the Air Vehicle Technology Office of the Defense Advanced Research Projects Agency of OSD and was responsible in that capacity for many experimental aircraft programs. He has well over three thousand flying hours as a command pilot which include aircraft ranging from light airplanes to supersonic military fighters. He is an Air Force veteran of the Vietnam conflict, where he flew 280 combat missions as a forward air controller. He was awarded the Distinguished Flying Cross and the Vietnamese Cross of Gallantry with two clusters by the South Vietnamese government. Dr. Krone is Chairman of the AIAA Advisory Committee on National Aeronautics.

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APPENDIX

CONGRESSIONAL AERONAUTICAL
ADVISORY COMMITTEE

REPORT TO CONGRESS

ASSESSMENT OF THE NASA AERONAUTICS BUDGET FOR FY 87

RECOMMENDATIONS

APRIL 9, 1986

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1. INTRODUCTION

AERONAUTICAL CHALLENGES

The Congress obviously faces many difficult and complex issues each year in considering and acting on the federal budget. The Congressional Aeronautical Advisory Committee was founded last year by the Congress to provide it expert advice on government programs for one segment of the budget. Under our charter, we are to advise the Congress on aeronautics in general and the NASA's aeronautics budget in particular.

Aeronautics has an enormous impact on the economy, security, and welfare of our nation. The atmosphere that surrounds earth is a vast fluidic sea through which speed large numbers of craft. Many are armed and dangerous. Others carry millions of travelers and thousands of tons of commercial goods of all kinds to every part of the world. Aircraft can rapidly project massive distraction and deploy forces anywhere in the world. Aviation allows businesses in large cities and small towns throughout our nation to shop anywhere and sell to the world. Aircraft make it possible to economically utilize world wide pools of labor, talents, and industrial capacity for our products. Aviation brings fresh food from the sea and land from distant parts of the country to our tables. The sale of aviation products themselves has been a greater positive factor in our international balance of trade relative then any other type of manufactured goods. The pervasive impact of aeronautics on the security, economy, and welfare of the United States is tne reason that Federal Government plays a major role in aeronautical research and development. As a result, we are a great aeronautical power among nations.

There are serious challenges ahead for this nation in aeronautics. We face challenges in every segment of aviation; military aviation, commercial transports, general aviation, civil helicopters, and related propulsion systems. In every area, we can and must develop markedly better aircraft over the next 10 to 20 years. Consider some of the challenges ahead for America in to aeronautics.

Military Aviation - There is much said about the Strategic Defense Initiative in terms of defense against ballistic missiles. However, strategic defense must include counter balancing forces and effective defense against the growing threat from Soviet strategic aircraft and cruise missiles. We must make great strides in technology to provide an effective defense against these threats. The Soviet Union has a strategic bomber force of about 450 aircraft, as compared to 330 U.S. bombers. The Soviet force includes roughly 135 modern supersonic Backfire bombers. There are another 125 Backfires used by the Soviet Navy for long range strikes against our fleets. This year the Soviet Union put the advanced intercontinental Blackjack bomber into production. The Blackjack is supersonic and it is larger than the B-1B. This new Soviet bomber will present the continental United States with a serious strategic air threat, as well as posing a greatly increased air threat to our naval fleets world-wide. At the same time, they have been adding long range cruise missiles to production bombers. There are 40 intercontinental Bear-H

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bombers, which have a new cruise missile with a range estimated at 1800 miles. In the future, any bases in Cuban and Central America would also allow the Soviet Union to directly use the Backfire and additional shorter range fighter-bombers against the continental United States. Hence, the Soviet Union is continuing to advance the technology of their large and rapidly growing force of intercontinental and naval strategic bombers.

We must improve our aeronautical capabilities for both strategic offense and defense. The United States is making strides technologically in our strategic bomber force capabilities with the addition of the B-1B, cruise missiles, and the ATB program. Still, the massive Soviet air defense system will grow and pose new challenges to maintaining our offensive deterrence capabilities. The Soviet Union has over 1,200 fighters interceptors and over 9,000 surface-to-air missile launchers for strategic defense. However, the United States has only 252 air defense fighter interceptors and no surface-to-air missile launchers. There is a serious imbalance here considering the technological and numerical advances in the Soviet strategic bomber force. We must improve our nation's aeronautical defense if strategic defense is to be effective. The fundamental aeronautical R&T in the NASA's program must help us to do it at the same time as it will benefit other segments of aeronautics vital to this nation.

The growing threat to the continental United States, as well as to our naval forces from the Soviet Union's submarines, requires more emphasis on Naval patrol and attack aircraft. Here advances in subsonic transport aircraft and propulsion technology, as well as helicopter technology will have a marked influence on our ability to detect and intercept submarines. The Soviet Union currently has 375 submarines of which 75 have ballistic missiles and 66 have cruise missiles. The Soviet Union is adding a long-range strategic cruise missile to the new Typhoon submarine; the world's largest submarine. By way of comparison, we have about 95 attack submarines.

The United States currently has a large advantage in naval air and sea power, but the Soviet Navy is growing and they are building full size carriers for the first time. In addition, the large Soviet land-based long-range naval bomber force poses a major threat to our naval fleets. We have no equivalent capability. There will be a need for new aircraft technology to provide U.S. carrier aircraft higher speeds, greater striking ranges, and longer endurance. The U.S. Navy is planning to develop a new attack aircraft called the Advanced Tactical Aircraft (ATA) and to use the Air Force's Advanced Tactical Fighter (ATF) for the air superiority mission in the early 1990's. In addition, at some point in the future, it will become clear that we must make greater use of long-range land-based aircraft, including strategic bombers, for use against naval targets of all kinds.

The Soviet Union continues to develop new advances in tactical flighters and fighter bombers. They have recently introduced the MIG-29/Fulcum high performance aircraft into service. This aircraft is an all weather, counter air fighter-intercepter with an improved missile. The SU-27 Flanker all-weather

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air superiority fighter, similar to the F-15, just became operational this year. These aircraft have a beyond-visual-range missiles. For close-air support, the Soviets have developed and recently deployed the SU-25/Frogfoot. These new Soviet aircraft are formidable advances, although they do not match the avionics capability of corresponding U.S. tactical aircraft. The U.S. Air Force Advanced Tactical Fighter program (ATF), an advanced air superiority fighter, will enter the first major place of its development this year. When it enters services in ten years, it will be the first all new tactical fighter developed by this country in over 15 years. We must continue to press forward on new research, technology, and development programs for naval and air force tactical aircraft in order to provide our pilots superior fighting machines in the future.

The Soviet Army is a very large and highly mobile modern fighting force. For example, the Soviet Union has 52,600 main battle tanks compared to about 13,500 American tanks. Warsaw Pact tanks outnumber NATO tanks in Europe two to one. The efforts to offset such large differences in armies must come from more advanced technology on our side. In a highly fluid war, the helicopter is an effective means for providing mobile fire power, as against tank columns, and for transportation of troops and supplies. The United States and NATO helicopters outnumber those of the Soviet Union and the Warsaw Pact, respectively. The United States has about 9,000 military helicopters versus 7,000 in the USSR. However, the Soviet Union is second to none in capabilities of their advanced helicopters. The Soviets emphasis on a heavy lift helicopter transport capability is reflected in the development and recent appearance of the Mi-26/Halo. It is the world's largest production helicopter, capable of carrying 90 combat loaded troops. A more advanced new high speed helicopter, Hokum, reportedly is expected soon to give the Soviets a significant rotary-wing air superiority. The Hokum will be the world's first, air-to-air, fighter helicopter which adds a new dimension to aerial warfare. None of our current helicopters have air-to-air capabilities. A new Soviet attack helicopter, the Mi-28/Havoc, similar to the U.S. Army Apache (AH64) is expected to be deployed in the near future.

Potential future war situations will require greater helicopter speeds, more stealth, greater effectiveness, and all at affordable costs. The U.S. Army has embarked on the development of an important new attack and utility helicopter called the LHX. The Navy's tilt rotor V22/Osprey will also be important to Naval and Marine capabilities. We must continue to press forward on research and technology for advanced rotary wing aircraft in order to field superior helicopters to support our ground forces. NASA's fundamental research and technology in this area must strongly support and continue to be closely linked to Army laboratories, which are co-located at NASA centers. Advances in military helicopters lead to advances in civil helicopters.

The Army will require close air support from both helicopters and fixed wing aircraft in order to counter balance the greater numbers of troops, fire power, and ground mobility of Communist block ground forces in Europe. Such aircraft would also support army operations in other areas of the world. This will eventually lead to a need for a new highly advanced subsonic close-air support aircraft that will deliver great fire power and survive in an extremely hostile battle environment. This aircraft probably would operate in the high subsonic

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speed range. They should be inexpensive, rugged, and capable of forward basing with minimum support. Fundamental aeronautical R&T for such aircraft can also benefit general aviation.

In order to project forces globally, a nation must have air transports as well as naval power. The Soviet Union has made great strides in military transports, many of which are being used to support the war in Afganistan, supply military forces in Africa, and aid some nations in this hemisphere. The Soviet Union has over 3,000 military transports of various sizes in the different elements of their military services. Soviet Military Transport Aviation has the primary responsibility for long-range and medium-range airlift transport. There are about 600 Soviet medium and long range airlift transports. For comparison, the United States has about 800 medium and long range military airlift transports. Soviet transports now have cargo capabilities and ranges similar to all our military transports, except the C-5A. The Soviets are currently developing an aircraft called the Condor which will be comparable in size to the C-5A. This aircraft will probably enter service either this year or next year.

Our ability to rapidly deploy to and operate in Europe and other areas of the world is a deterrence to any aggressor nation where we have vital national interests. Research and technology for military transports are largely applicable to civil transports. We must continue to press forward in these areas to develop, improve, and field more efficient aircraft of varing ranges and cargo carry capabilities. The United States is developing the C-17 as a new strategic transport. There will also be a need to replace the C-130 with an advanced medium range transport that is efficient and highly survivable. In addition, versions of civil transports are needed for advanced air warning and control and as tanker aircraft for tactical strategic and defensive applications. Hence, subsonic transports will remain a major technological challenge in the years to come. Needed advances in airframes, avionics, and propulsion for these military aircraft are largely common to many of areas where we need to press forward in basic R&T for civil transports.

Commercial Transports - There is a growing need for more and better commercial transports. The World's scheduled airlines carried passengers on about 830 million trips in 1984, which represented an increase of 62 percent in 10 years. In that same year these airlines carried 14 million tons of freight following a similar percentage increase in demand from a decade earlier. U.S. air carriers carried the public on over 300 million trips in 1984, about half of which were for business travel. Civil Airlines must meet the demand.

At the same time competitive pressures and rising operating costs have intensified the need for more efficient and easier to maintain transport aircraft. The public ultimately receives the most benefits from lower cost air transportation through growth in the economy and more affordable personal travel. One has only to look around any airline terminal to gage the impact on our society. Economic growth is stimulated by the business expansion made possible by lower cost air transportation.

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Intense competitive pressures have been created for U.S. civil transport manufacturers by the growth of foreign competition with strong foreign government backing. Deregulation has placed great economic pressures on airlines. Reduced demand for new transports due to low airline earnings and the capture of sales by foreign competition have reduced U.S. transport sales. Annual deliveries of U.S. commercial jet transports dropped from 387 to 185 aircraft between 1980 and 1984. Airbus industries introduced a wide range of transports competing with almost all U.S. commercial transports, except the largest wide bodied jumbo jets (747 and derivatives). We witnessed one U.S. manufacturer, Lockneed, got out of the civil transport business in the last decade. At the same time, Airbus introduced new aircraft. The airbus A-320 will enter service in 1988 with no direct U.S. competitor in terms of capabilities. However, McDonnell Douglas' MD-80, a derivative of the DC-9, provided competition for the A-320 because of the MD-80's overlapping capabilities and its lower purchase price. Airbus' board recently approved further development of widebody transports, the A330 and A340, with a goal of entry into service in the early 1990's. These new transports will give Airbus a full product line competing with all U.S. transports. Airbus' stated goal is to double their market share 35 percent. The Airbus products are particularly appealing to European air carriers and there is keen competition everywhere for sales. International Airbus sales are supported by large incentatives; usually government backed or part of unconventional government package deals.

United States manufacturers, Boeing, and McDonnell Douglas compete by offering increasing product capabilities, quality, reliability, good support, and commercially viable incentatives. The next generation of U.S. transport aircraft can make a major leap forward by taking advantage of new research and technologies, much of which is emerging from the NASA aeronautics programs. Technology is the battle ground for subsonic transports and economics is the determinant for winners and losers. Fundamental research and technology from NASA programs can make the difference in the results for U.S. subsonic transports.

The French and British have had the clear lead in supersonic transports. They have one and we do not. The Concord has not been a significant market factor to date, but these governments were willing to pay the price for development and years of operational loses. Now, reportedly, Aerospatiale has plans for a new and more efficient supersonic transport. Compared to the Concord, it would carry twice as many passengers, cruise at 1,700 vs 1,350 mph, and have a longer range. The questions are (1) can the United States develop a commercially viable long range supersonic transport using new technology and (2) should we do it? If the answers to these questions both turn out to be positive, then it will require a major increase in research and technology toward this end.

General Aviation - General aviation in the United States is markedly depressed. Forty years ago in 1946, right after World War II, our general aviation industry sold 35,000 aircraft. The returning former military pilots of that war wanted to fly. They could afford a new light airplane for personal and business uses and many established aviation services. General aviation grew in the following years as means of transportation; i.e., for business, air taxies, commuter services, and for recreation. The last peak in general

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aviation sales occurred in 1978 with a delivery of 17,000 aircraft. Business executive and commuter aircraft had taken on greater importance in the market share. We then witnessed the entrance of foreign manufacturers into these markets, with the strong backing of their governments.

The general aviation situation in the United States turned extremely serious after 1980 due to economic pressures and foreign competition. The U.S. industry sold only 2,400 aircraft in 1984, a drop of 85 percent relative to the number of units sold six years earlier. Foreign competition is intense for both commuter aircraft and executive jets. The higher priced end of the market is where the strongest sales are occurring; i.e., in executive jets and business commuter aircraft. Here we are engaged in a major technological competition with foreign countries. The costs for general aviation aircraft have grown out of reach of the public and there has been a corresponding collapse of the market for new light aircraft sales.

General aviation is a vital national resource. Consider the sheer magnitude of their numbers and the many uses for general aviation aircraft. There are 213,000 active general aviation aircraft in the United States. A total of 62,000 of these aircraft are used for business and executive travel; 102,000 are for personal use; 15,000 for instruction; 7,000 for aerial applications such as agriculture and medical evacuation; 6,000 for police, boarder security patrols, mapping, and other types of aerial observation; another 8,000 for commuter airlines and air taxies, and a total of 13,000 aircraft for rental and other applications. There are about 640,000 active general aviation pilots in the United States. The numbers indicate the great demand and broad uses for general aviation aircraft in the United States.

General aviation is important for private business, public transportation, health, public safety, and recreation. This segment of aviation is particularly important to the vast number of people living and engaged in businesses in rural areas and small towns all over the country. It is a source of pilots for the military services and for commercial aviation. General aviation provides basic training aircraft, light observational aircraft, and utility aircraft for the military services. General aviation is an integral part of the total inter-related complex of aeronautical capabilities that makes this nation a great aeronautical power.

There are basic challenges that must be met if we are going to have a vibrant general aviation sector in this nation's vast aeronautical complex. Technological advances are needed to achieve longer range, better performing, and more efficient aircraft at the higher end of the market. We must make advances that will make it possible to own and operate less costly light aircraft. Reduction of product liability costs is extremely important, but this is a matter of law. We also need new technology that will increase the safety of the flying public for all aircraft. NASA's fundamental research and technology programs can help provide advances in all classes of general aviation aircraft.

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Civil Helicopters - There is a close relationship between R&D for civil and military helicopters. American helicopter companies develop both military and civil helicopters. Often versions of the same helicopter are used for both applications. Most advances in military or civil helicopter technologies and designs generally lead to gains in both.

The U.S. helicopter industry is also under enormous pressure. American civil helicopter sales peaked in about 1980 when the annual deliveries were about 1400 units. The civil applications of helicopters greatly expanded in the last decade to include off-shore transportation for oil and gas wells, executive and business transportation, logging, construction, fire fighting, observation, medical evacuation, public safety, and many others. However, the U.S. helicopter manufacturing industry also ran into intense competition from government-backed foreign companies. About one half the world's sales in helicopters are made in the United States. Yet, slackening demand and increased foreign competition have led to a 1984 sales level for U.S. helicopter companies of only about 330 civil helicopters; about half the dollar sales volume of just five years ago.

The impact of foreign competition is clear. In 1980 a total of 82 percent of the entire world fleet of turbine powered civil helicopters was manufactured in the United States. Just four years later, in 1984, foreign competition had reduced the percentage of helicopters manufactured in the United States to 68 percent. We are engaged in a great technological competition with foreign, government-backed, helicopter manufacturers.

Advances in technology for civil helicopters are needed to increase their performance, range, efficiency, safety and capabilities for a variety of uses. It is important to find ways to reduce costs, including the helicopter price and the cost of operation. Major new capabilities are possible from research and technologies. There can emerge a whole new generation of helicopters with new designs, structures, propulsion and controls. There will be designs that can function like a helicopter for takeoff and landing, and also fly like a fixed wing aircraft for efficient cruise. The Army programs and the Navy tilt rotor programs, along with NASA's basic R&T, can bring forth major advances in civil helicopters.

The competition with foreign manufacturers is intense and we must press forward without any let up. Conventional helicopters will be improved in major ways; by less parts, lighter weight structures, better control and guidance, lower noise, better propulsion and more efficient overall designs. The mutual benefits to both civil and military helicopters will more than justify the relatively modest front end cost for fundamental research and technology. NASA and the Army are linked by colocated and inter-related laboratories and facilities in this role. NASA must not back away from this special role.

Propulsion Systems - The most important gains in aeronautics have stemmed from new propulsion systems. Sales of engines and parts to the U.S. Government have risen steadily since 1972, resulting in sales of $5 billion in 1984. Sales to the civil sector and foreign military sales also rose steadily until 1979 when they flattened out to the range of $4.0-4.6 Billion. Foreign technology in propulsion

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systems is good; it has been steadily improving and they are offering a wider range of engines. We are in a technological competition in propulsion systems with friendly allies for sales and with the Soviet Union for superior propulsion for military aircraft. The technological competition with friendly allies is evident in all areas. For example, consider activities relative to the propfan propulsion. France tested a 12-bladed propfan recently. The Charme project was launched in 1982 by the French government in cooperation with Onera, Aerospatiale, and prop manufacturer Ratier Figeac. A 39 inch diameter prop was recently tested in the wind tunnel at Modane. The next phase of development will be on counter rotating propfans.

Rolls is positioning themselves to produce Propfan engines in 1993 for 150-seat class transports. For future 40,000-60,000 pound thrust requirements, they are pursuing a counter rotating propfan engine concept. Japan's five heavy industry firms reportedly have agreed to form an organization this spring for joint research and development of a propfan engine and propeller. The proposed funding level is about $220M over six years. The Japanese have reportedly begun a fuel efficient aircraft technology experimental research program (FEATHER). The goal of this program is to be able to start design in the year 2000 of a transport aircraft that will be 50 percent more fuel efficient than the 767. This project reportedly is 100 percent government funded at $200M at the current time. Milestones are an advanced engine demo followed by an advanced aircraft flight test in 1997.

Foreign governments have target aeronautics, in general, and their propulsion systems as national industrial goals. In order to retain our lead, we will have to increase our efforts in stimulative fundamental research and technology to provide major advances in aircraft and propulsion system design. The pace of our efforts must be increased and we must seek to leverage our investments.

NASA's Role - The challenges we face in aeronautics will lead us to substantial gains in the capabilities of military and commercial aircraft; but only if we face these challenges head on. There are major advantages to conducting much of the high-leveraged front-end research and technology in NASA. NASA can centrally supply large test facilities, basic theories, methods, design data, and innovative component design concepts that will reduce the need for duplication of efforts elsewhere. Much of this basic work has common application to various types of aircraft for both military and civil applications. It is also advantageous and even necessary that the more applied portions of these NASA programs, particularly expensive flight test programs, be conducted jointly with the military services. Partnership arrangements between NASA and industry can also be an effective means of sharing tasks and focusing national assets on long term aeronautical technology. NASA must be a true consistant partner with industry and other government agencies engaged in aeronautics and be responsive to their long term needs. NASA has been using these approaches in general.

THE ADVISORY COMMITTEE AND PROCEDURES

This report presents an assessment of NASA's aeronautics programs and related budgets for FY 87. The reviews and recommendations presented here represent

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a consensus of judgments of the Congressional Aeronautical Advisory Committee.* A list of members of the Advisory Committee is given following the first page of the report and resumes of their background may be obtained from the Executive Secretary of the Committee. The members of this committee were chosen from among this nation's most outstanding leaders and experts in aeronautics. They were selected to provide a careful balance of backgrounds from every sector of aeronautics: commercial and military transports, general aviation, high speed aircraft such as fighters and bombers, civil and military helicopters, trainers, and propulsion systems. The members came from the aircraft industry, the three military services, and from universities.

The Congressional Aeronautics Advisory Committee is qualified to provide this assessment of NASA's aeronautics programs for the following reasons. This advisory committee is basically composed of experts and representatives of the ultimate recipients and users of NASA's aeronautical research and technology. In the space program, NASA conducts its own research and development programs, purchases final flight vehicles, and conducts extensive flight operations. However, in aeronautics, it is important to take account of the fact that NASA is not the end user of the research and technology that it produces. The entire NASA output goes to the american aeronautics industry, the military services, and other government agencies. Therefore, a committee composed of leaders from all these sectors is qualified to assess the priorities and importance of NASA's aeronautics programs. The committee members are also from organizations that conduct aeronautical R&D. They can provide fully qualified judgements as to the appropriateness of NASA conducting aeronautical research and technology programs in relation to programs that would naturally be supported or best conducted by other sectors of the aeronautical R&D community. Finally, when the members of such a broad group of experts from organizations with diverse and often competitive interests agree on wide-ranging assessments and recommendations, it indicates that there is common understanding and recognition of what needs to be done by NASA in the overall national interests.

The committee was carefully selected to provide a balance of interests from the various sectors and to avoid personal conflicts of interest. Strict operating procedures were used to avoid situations in which the committee as a group would be biased or where there would be a strong conflict of interest relative to a member's company. For example, no member could be present at times when the committee evaluated the priorities or funding for any program for which that member's company either had or would be bidding on a substantial contract under that program. No lobbying of the committee members outside of the meeting was allowed by such members either. However, open discussions during NASA

*A consensus means that a greater-than-two thirds majority of this committee shared the opinions presented. Opinions were formulated by a structured assessment process that included closed voting on all points in the testimony, except the introduction. The introduction was prepared by the committee chairman. Any given point of view does not necessarily represent the individual opinion of every member of this committee.

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presentations were allowed to surface contrary points of view.

REPORT ORGANIZATION

The report is divided into four main sections. First is the introduction. The second is an overall assessment of the general direction of NASA's programs and budgets for aeronautics. This section also addresses some general committee findings and concerns based upon our overall assessment. The third section of the report presents concluding remarks addressing limitations of the assessment and of some committee members which were not addressed or were not agreed upon. The fourth part of the assessment presents evaluations and recommendations for the specific NASA FY 86 aeronautics budgets presented to Congress. This portion of the assessment is presented in the form of tables with priorities for the programs, analyses of the budgets, and recommendations for changes. The fourth portion of the assessment is complete enough to be separated from the rest of the report and used alone in a brief form.

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2. GENERAL FINDINGS

EMPHASIS ON AERONAUTICS IN NASA

The relatively low level of support and emphasis placed on aeronautics in NASA are not commensurate with the major challenges that this nation faces in this area. The National Aeronautics and Space Administration budget for aeronautics totals only about 9 percent of NASA's 7.7 billion dollar budget. The NASA budget for aeronautics has been relatively flat for about four years, in real terms. Accounting for the effects of inflation, this budget level is lower than at any time during the decade that preceded it. Our review of the NASA's aeronautical research and technology programs indicates that the level of activities in many areas are substantially less than those needed to move forward by large enough steps or at a great enough pace to meet the clear challenges before us in aeronautics.

NASA supports research and technology for both space and aeronautics. Since the reorganization of the National Advisory Committee for Aeronautics into the National Aeronautics and Space Agency, heavy emphasis and commitments to space operations has had the effect of understressing its crucial role in aeronautics. Flight in our atmosphere is a vital national interest for both civil and military aeronautical systems. The needs for fundamental new advances are increasing, not decreasing with time. NASA management needs to recognize its critical obligations to aeronautics and should strive to achieve a balance in its organization, stated objectives, and assignment of budgets commensurate with that dual role. The Committee is concerned that aeronautics has been relegated to a position far lower than its importance and contributions to the national interests.

The question of why this nation has a central aeronautical R&T organization such as NASA has been answered by over 70 years of successful results. It is because this management formula works. For this reason, other countries have copied this same management scheme. From the earliest days of a aviation, NACA and later NASA provided a central source of research expertise producing innovations, methods, and data for all segments of aeronautics in this country. Thus, the research and generic technology, obtained centrally, is commonly available, economically, to industry and the military services. NASA provides a central organization for acquiring and maintaining major aeronautical facilities that are used for this research and these facilities are also commonly available to other aeronautical organizations in the United States. This management formula has been extremely cost effective because it avoids duplication and provides a central flow of high-leveraged, front-end research and technologies that would not otherwise be available.

*The NASA budget categories do not reflect these divisions of programs.

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OVERALL ASSESSMENT OF AERONAUTICS PROGRAMS

The advisory committee strongly recommends favorable action on NASA's aeronautical programs and the submitted FY budgets, without revision. The accompanying budget tables give our detailed assessment of the elements of NASA's submitted budget. We advise the Congress to include at least a $1.5 million augmentation to the FY 87 aeronautics budget for adjustments to a few important programs given in the tables. However, these changes should be true augmentations and not just realignments within the budget. In addition, we wish to make it clear that our recommendations should not be taken as advising against additional funding augmentations that the Congress may feel are important this year beyond our recommended funding level. This year our recommendations were formulated with every attempt to reduce the NASA aeronautics budget to the lowest realistic level in light of the uncommonly severe pressures on the national budget. The fact that we may not have recommended increases in particular programs this year by no means indicates that the committee was satisfied with the level of effort on those programs. Our trust is that there will be an opportunity for appropriate real increases in the NASA aeronautics budget in the future years.

We believe that NASA is pursuing the correct paths in its FY 87 aeronautical program. NASA has made a concerted effort to provide a broad and well balanced aeronautical research and technology program for this year. The submitted budget addresses the major aeronautical challenges of the future, as well as can be expected at this time, within the given budget constraints. All of the programs are necessary and properly belong in the budget. We reviewed a total of 69 programs comprising the entire FY 87 aeronautics budget. We rate the priorities of these individual programs roughly as follows:

	Percent of Programs
Extremely important	8
Very important	27
Important	57
Worthy	6
Boaderline	2
Unsatisfactory	0

The divisions between these categories are highly subject to interpretation, particularly at the interfaces. But it is clear that these ratings are higher than last year and reflect well on the overall quality of the aeronautics programs submitted. The programs rated in the top two categories increased by roughly 15 percent.

Our strong endorsement of the NASA's FY 87 aeronautics programs and budgets was influenced by adjustments that NASA made to the FY 87 budget reflecting specific changes in budgets and emphasis that we urged last year in our report to

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Congress. The advisory committee's funding tables later in this report point out the considerable extent to which the submitted budget and planned programs satisfy last year's recommendations. Hence, the advisory committee has little reason to critize the NASA aeronautics budget for FY 87.

The extent of the changes in emphasis and budget that we advised the Congress to make last year were important. We recommended changes in the FY 86 aeronautics budget totaling $36.7 million. There were six specific program increases amounting to $20.2 million and four program decreases totalling $16.1 million. We recommended canceling three facilities related programs which were diverting between 100 and 200 NASA engineers and scientists from more important aeronautical research and would have later cost over $300 million additionally for the resulting facilities. Furthermore, NASA indicated to us that the FY 87 alterations are the beginning. NASA intends to correct most of the serious concerns that we expressed to Congress regarding the balance of NASA's aeronautical research and technology and the changes in emphasis needed. When we carefully reviewed the NASA detailed programs for FY 87, related budgets, and future plans, we found that they were fairly well in line with our recommendations to Congress last year.

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THE NATIONAL AEROSPACE PLANE PROGRAM (NASP)

The NASA portion of the National Aerospace Plane budget ($45M) was submitted as an item completely separated from the aeronautics budget. We believe that this distinction is correct. The advisory committee strongly recommends that the aeronautics budget should remain separate and apart from the National Aerospace Plane. The National Aerospace Plane should be evaluated on its own merits in relation to its funding requirements. This program would kill a substantial number of important aeronautics programs for transports, general aviation, helicopters, and high performance aircraft if funds for it were taken out of the submitted aeronautics budget for FY 87. The requested funding specifically for the National Aerospace Plane equals 16 percent of the total Aeronautical R&D (contract) budget. In fact, the funding for this large program equals 21 percent of the Aeronautical R&D (contract) budget by adding in the funds directed toward this program currently in the submitted FY 87 aeronautics budget for hypersonic research. The impact of such a cut in important programs in the aeronautics budget would be extremely serious. The National Aerospace Plane is a highly specialized vehicle. This program has little in common with the general proposes or technical thrusts of the prime aeronautics programs in the NASA budget. The character of National Aerospace Plane and size of its budget make it advisable to keep it separate from the aeronautics budget.

The advisory committee has not evaluated the adequacy or importance of the submitted NASA National Aerospace Plane program and related budget. In order to properly advise the Congress in this regard, the committee would have to understand the total breadth of the applications, technology, readiness, requirements, program plans, management, and NASA's participation in the program. The advisory committee did not review enough of this information to make sound recommendations on the program. Furthermore, much of the information on this program is classified and could not be made available to the entire committee. The committee has many members whose companies are bidding on the Air Force's Trans-Atmospheric Vehicle (TAV) program. According to the committee's rules of conduct, these members may not participate in the deliberations on the National Aerospace Plane because this program and those contracts may be strongly affected by the NASA funding for National Aerospace Plane. The remaining advisory committee would not have had enough expertise on it to consider this program properly. All-in-all, we did not believe that we could or should evaluate the National Aerospace Plane program at this time.

MAJOR CONCERNS

In spite of our positive assessment of the FY 87 budget, we must still express some serious concerns. These problems cannot be solved this year by altering in the FY 87 NASA aeronautics budget. They are problems that must be corrected by changes next year and beyond.

Our primary concern is the lack of emphasis on aeronautics in NASA; in regard to its primary goals, funding, and organization. Some dramatic changes are needed in all three of these areas to put NASA on the right attack in aeronautics.

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We are seriously worried about the errosion of fundamental aeronautical research and technology in NASA. This area is often called the R&T base. However, fundamental aeronautical research and technology efforts cannot be equated to the work in the NASA budget category called the R&T base, although much of it is fundamental. The R&D process may be divided into these five segments. Starting from the beginning of the R&D process, we have basic research, then applied research, generic and component technology development, systems technology development, and then product development.* Basic research is to gain fundamental knowledge of nature using theoretical work and experimental observations. Applied research is also research to obtain fundamental knowledge by the use of theory and experimentation, but it is aimed at obtaining a body of knowledge to solve certain classes of problems. Technology development is use of existing knowledge to create or enhance the art and engineering capability to develop and produce particular types of products. Generic technology development is that which applies to a fairly wide spectrum of applications, which often includes work in component technology development. Component technology development addresses improvements in system components, parts, devices, and the methods for using them. System technology development is the improvement in the capability to combine components and technology enhancements from different technical disciplines into rudimentary systems for a narrow class of product applications. System technology includes programs that may be called bread boards, hardware demonstrators, technology demonstrators, or research aircraft. Applied research information may also be gained from research aircraft if the program is properly planned and conducted. The final phase in the R&D process is product development where the actual aircraft is developed. The development phase includes all product requirement and conceptual design studies, feasibility studies, preliminary design, initial prototypes, final design construction, and testing development prototypes. The costs of aeronautical R&D programs typically increase by roughly an order of magnitude from one phase to the next, as programs become less fundamental and more applied.

We are concerned about the errosion away of fundamental small-size aeronautical research and technology in NASA's programs. Our primary worry is about applied research programs, but we are also seriously concerned about generic technology including component technology development. These smaller, less expensive programs are being killed off and squeezed by the large, costly, highly focused systems technology hardware.* The fundamental research and technology programs provide the genosis of the knowledge, methods, concepts, and innovations that lead to the major advances in aeronautics. However, these programs involve complex theories, experiments, and concepts. The fundamental programs behind these gains simply are not as visible or easy to understand as the large flight hardware programs. In great measure, Congress itself has been responsible for this situation because of a natural inability to recognize the relevance of such basic work. Congress has directed budget cuts against the "R&T base" to fund large hardware programs, wiping out great numbers of the small seed programs needed for major future advances. The National Aerospace Plane would be the biggest blow of this kind, by far, if this program is funded out of the tightly strained

*The NASA budget categories do not reflect these divisions of programs.

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aeronautics budget. NASA realized years ago that it is easier to describe and sell programs in the later stages of the R&D process to the Congress. As a result, there has been less and less emphasis on the fundamental aeronautical research and technology programs in NASA. Yet, these early stages of R&D are where NASA plays its most important role in aeronautics. As a result, fundamental innovations are drying up and advances are coming increasingly at the expense of greater design complexity.

The escalating costs for facilities, i.e., construction, operation, and maintenance is another factor that has cut into the funds available for fundamental aeronautical research and technology in NASA. New expensive facilities are highly visible and they appear to add value and solidity to an institution. However, costs for the most expensive facilities are increasing beyond reasonable bounds as a percentage of the NASA's total aeronautical budget. NASA must devote close attention in considering new facilities; not only to the initial costs but also to the affordability of the later operations costs.

One of NASA's most difficult management tasks is balancing the expenses associated with facilities against the resources required for direct research and technology work. NASA management is paying greater attention to this problem and has made some very difficult decisions to reverse this trend. Still, we continue to be concerned about NASA's aeronautical R&D centers becoming primarily national aeronautical test services and huge computer centers without retaining the resources required for creative original in-house and sponsored research in aeronautics. If NASA's operating budget cannot be increased commensurate with the additional support needs of its expanding capital plant, then the inevitable result will be a continued shrinkage of the core research and technology programs and a long-term reduction of NASA's aeronautical expertise.

At the same time, NASA has an extremely important national role in the operation of its large complex or existing aeronautical facilities for in-house research and use by industry, the military, and other government agencies. We are particularly concerned about the deteriorating condition and lack of modernization of NASA's older wind tunnel facilities. NASA has many wind tunnels that are in high demand today and which are likely to remain so for the forseable future. A number of these important NASA tunnels are either inoperable, in poor states of repair, or are operating at reduced capabilities. One such example is the Low Speed 12-foot Pressure Tunnel at Ames Research Center. This facility is a unique and important national resource. It is important because of its large test section and flow capabilities which, at reasonable cost, will allow testing aircraft at high angles with a good simulation of full-scale flight. However, the 12-foot pressure tunnel is currently operating at great reduced pressures because of structural fatigue problems and, as a result, it cannot provide good simulations of flight conditions. This facility should be rapidly inspected for flaws, repaired, recertified for its full pressure conditions, and modernized to provide higher productivity. A modernization program for older high-demand facilities will reduce operating costs, particularly with better instrumentation, data processing, and recording capabilities. When a facility is no longer in high demand, and only then, should it be considered time to close it down. New facilities may get higher visibility but ultimately it is the relative worth of the data and the affordability of the costs for facilities

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that determine their value to aeronautics.

Finally, we must raise a serious question as to the adequacy of the NASA's planning, budgeting, and management accounting methods for its aeronautics programs. The establishment and use of a proper management system for planning, budgeting, and tracking funds expenditures and manpower allocations to programs is the first principle of sound R&D management. It is exceedingly difficult to determine the amount of funds or manpower planned or expended on most of NASA's specific aeronautics programs. We noted that many people in NASA including upper management had as much difficulty as we did in this respect.

There are a huge number of inconsistencies in the allocations of different types of expenditures for different programs. The budget categories are not always descriptive of the work and many programs are divided among budget categories. Budget categories are continually changed and work is often shifted beneath different budget categories every year. Specifically, we found the following:

- There is no clear distinction between programs listed in the R&T base relative to those listed under system technology. In fact, there were significant expenditures in the R&T base that were actually supporting programs under Systems Technology.

- The costs for operating facilities are sometimes allocated completely to the projects supported by these facilities, other times they are allocated completely to central facilities projects, and sometimes they are accounted for under both of these categories. Individual centers accounted for facilities expenditures differently, with varying degrees of consistencies from excellent to poor.

NASA was unable to provide the advisory committee any manpower planning figures for its projects at all this year. The efforts of NASA's over 3,000 people in aeronautics accounts for roughly half of the total NASA budget for aeronautics. This funding is covered under the category called "Research and Program Management" in the NASA budget. It is impossible for NASA management, this advisory committee, or anyone else to determine how much effort is going into the various NASA aeronautics projects, i.e., the total funding for them, without clear planning and tracking of the manpower.

In many respects, we noted improvements in NASA's management planning and accounting methods this year, but NASA needs to establish a far better system for effective planning and management of the funds provided for aeronautics programs. It would be wise for NASA to examine the DoD's management planning and accounting system and the categories used for aeronautics as a point of departure. We do not recommend a total switch to this same system, but many features and the categories used by the DoD for aeronautics would provide improvements to the NASA system. However, many features of NASA's methods should be retained; for example, last year we found that the NASA Research and Technology Objectives Plans (RTOPS) and most aspects of their resource pages provided simple and effective planning tools. However, this year, the RTOPS were far too broad

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and vague to be useful. NASA would find that their work, procedures, planning, and reporting would become easier and more efficient with a better management planning, accounting, and reporting system.

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3. CONCLUDING REMARKS

The Congressional Aeronautical Advisory Committee conducted a detailed assessment of the priorities and funds for NASA Aeronautics programs related to the FY 86 budget. We are pleased to endorse this budget, with the recommended small but important augmentations. The Advisory Committee was able to provide a strong favorable recommendation to the Congress because NASA significantly adjusted its programs and related budgets for FY 87 along lines recommended by our committee to Congress last year.

There were some limitations to the scope of our assessment of NASA aeronautics programs. A number of committee members felt that a broader assessment should be conducted of NASA's long-term development as an institution and to address means to increase NASA's effectiveness in support of American aeronautics. This report contains some of these aspects but neither the assessment nor the recommendations were meant to be comprehensive. Many members of this committee wished to address the effectiveness of NASA's advisory committees in influencing NASA's programs. The congressional advisory committee may conduct a broader assessment that would address solely such general issues, at a time when we are not under the pressures and workload required to conduct the review of NASA's annual aeronautical budget submission.

Some committee members wished this report to point out that last year the committee made special mention of general aviation as an area of special concern along with rotorcraft, high speed aircraft, facilities, and computational fluid dynamics. They noted that the last four have changed for the better, but programs which can be directly related to general aviation remain and are projected to remain at the $10-11 million level. The only significant action on the part of NASA seems to have been the regrouping of programs so that the label "Subsonic Transport/Commuter/General Aviation," points out that they do have specific efforts in that area. These committee members were not as concerned that NASA should undertake a large dedicated general aviation program (labeled as such) at this time so long as this report points out the importance of the need to increase work in the following areas related to general aviation:

1. Much of the work labeled transport, commuter, fighter, rotorcraft has applicability to general aviation aircraft.

2. NASA should continue to maintain a very open attitude regarding cooperative programs. This enables the general aviation community to gain access to NASA's test facilities and expertise (and NASA to take advantage of industry experience and design and fabrication capabilities) at reasonable cost.

3. NASA is maintaining a long term (though probably under funded) programs in small engine development - both intermittent combustion and small turbine technology of value to general aviation.

The hope is that future budgets will allow the inclusion of additional appropriate research and technology programs for general aviation aircraft.

We should point out a situation regarding the number of the committee members that attended the final review of the NASA budget (see list of committee members after the title page). One member felt his group was underrepresented. He was also concerned that there might not have been sufficient technical expertise to advise on some issues when members, whose companies were involved in related contracts, were excluded from the committee discussions and voting. No other members expressed these concerns. The advisory committee chairman ruled that the committee present was sufficient and well enough balanced to provide unbiased expert assessments of the programs covered in this report.

The Congress will receive and evaluate a wide range of views on individual programs from outside the advisory committee. In addition, we encourage the members of Congress and their staffs to contact individual members of our committee for additional advice on issues that may or may not be covered in this report. We hope that our service will prove valuable to the Congress, to our nation's progress in aeronautics, and, ultimately, thereby to the people of the United States.

ASSESSMENT OF THE NASA AERONAUTICS FY 86 PROGRAMS & BUDGETS

ADVISORY COMMITTEE REVIEW

4. REMOVABLE BUDGET SECTION

GENERAL

The Congressional Advisory Committee on Aeronautics conducted an assessment of NASA programs and proposed budgets for FY 87. The Advisory Committee is composed of aeronautical leaders from every sector of aeronautics, including: manufacturing industry, airlines, the military services, and the academic community. A list of committee members appears after the title page of this report. The members selected for this Committee have expertise and broad knowledge that spans research, technology advancement, development, and operational requirements, as well as all major aeronautical technical disciplines. This group was chosen to provide a careful balance of backgrounds and interests from all segments of aeronautics, including commercial transports, military transports, general aviation, helicopters, military fighters and bombers, trainers, and attack aircraft. No one group had nearly enough votes to sway a vote in its direction unless a majority of the other committee members were convinced by logic and facts of the national value of that direction. Strict procedures were used to avoid conflicts of interest. We were able to reach a high level of accord because of our common interest in advancing this nation's aeronautics capabilities.

The Advisory Committee reviewed all of NASA's aeronautics FY 87 programs and planned budgets at NASA Headquarters and also reviewed Air Force aeronautical R&T programs during a visit to Wright Patterson Air Force Base. We visited all three NASA centers earlier in reviewing programs for the FY 86 budget. In addition, separate subcommittees conducted independent, fact-finding reviews of: (1) the Laminar Flow Control Program this year, (2) the planned Altitude Wind Tunnel (AWT) at NASA-Lewis last year, (3) the X-Wing Program last year, and (4) the Oblique Wing Program a little over a year ago.

This portion of the report has been written so that it can be used separately from the full report. The results of the Committee assessments are given in tables that relate to the budget breakdown submitted to NASA by Congress.

EXPLANATION OF TABLES

This assessment represents a consensus of judgments of the Committee (here, consensus means that a two-thirds majority vote or greater of the Committee were in accord on the judgments presented). Opinions were formulated by a structured assessment process that included closed voting on

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the priorities, funds, and major points in the report. Therefore, any given judgment does not necessarily represent the individual opinion of every member of this Committee or their respective organizations. The following is an explanation of each of the columns and the entries in the tables.

Budget Item - The first column in the table shows the budget items. First, there are summary tables for the major categories in the budget; then, there are more detailed assessment tables with the breakdown for each major category. The individual "discipline" categories in the budget are numbered in the report tables for reference. The tables show evaluations for each of these individual discipline categories identified by NASA in the budget under both R&T Base and Systems Technology programs. Under these discipline categories, also there are assessments of only the detailed programs for which the Committee advise particular budget constraints, or changes in the budget. In general, the Committee expects that the budgets of the other detailed programs that we reviewed will be consistent with the levels that NASA indicated to the advisory committee during presentations to the Committee, but we recognize that there may be a need to reprogram these budgets to some extent.

Submitted Budget - The second column in the table shows NASA's estimated FY 87 budget submitted to Congress or detailed programs presented to the Advisory Committee consistent with that submission. In some cases, NASA's specific figures were not available for FY 87 for detailed programs at the time. The second column is blank in these cases.

Recommended - The third column in each table shows the specific budget recommended by the Advisory Committee for the program. The Committee estimates the recommended funds from data supplied by NASA and from other reliable sources. Often, NASA expenditures for FY 86 or budgets planned for FY 87 are used to make the recommended estimates. The recommended budget for each numbered discipline item reflects the net results of the changes recommended for the detailed programs listed below it. The comments column often provides additional information about the recommended funds.

Priority Assessment - The Committee voted on program priorities using the subjective verbal descriptions of importance shown at the bottom of each table. The priorities for the numbered categories is a weighted average of the priorities for all the detailed programs under that item. The weighting factor was the total annual costs (R&D plus R&PM) for each detailed program. The bracketed numbers in the priority column, below the main priority, show the range of priorities for the detailed programs under the indicated overall discipline. Priorities are shown for detailed programs when there are recommendations for those programs.

Recommendations, Rationale and Comments - The last column is self-explanatory.

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NASA AERONAUTICS BUDGET FOR FY87

CONGRESSIONAL AERONAUTICAL ADVISORY COMMITTEE ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
SUMMARY OF TOTALS FOR AERONAUTICS				
NASA TOTAL AERONAUTICS BUDGET	702.2			The submitted NASA aeronautics budget continues at austere levels; it only amounts to 9 % of the total NASA budget. In real terms, this annual budget has been almost flat for the last five years; a level lower than in any year in over a decade that preceded it. Nevertheless, as was the case last year, the advisory committee once again evaluated NASA's aeronautics programs with the objective of keeping our recommendations within the submitted budget because of the extreme budgetary pressures on the government.
AERONAUTICAL R&D (CONTRACT)	376.0			We are pleased to strongly endorse NASA's submitted Aeronautical R&D contract budget for FY 87. NASA has made a concerted effort to provide a budget and a program plan that are properly balanced and well directed within severe financial constraints. Most of the advisory committee's recommendations last year have been included by NASA in the submitted FY 87 budget. As a consequence, we have little criticism of the submitted budget, but we have included some advise on it and minor recommendations for adjustments.
RESEARCH & TECHNOLOGY BASE	272.9	274.4		
SYSTEM TECHNOLOGY PROGRAMS	103.1	103.1		
RESEARCH AND PROGRAM MANAGEMENT	278.4	No Comment		The advisory committee did not evaluate NASA's manpower planned for FY 87 programs because this information was not provided to the congressional staff by NASA. We used last year's data to estimate total funding for each of NASA's planned FY 87 programs.

Priority/Importance

90 – Extremely important 70 – Important 50 – Borderline 30 – Minor 10 – Insignificant
80 – Very important 60 – Worthy 40 – Just below entry level 20 – Very minor

NASA AERONAUTICS BUDGET FOR FY87

CONGRESSIONAL AERONAUTICAL ADVISORY COMMITTEE ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
SUMMARY OF TOTALS FOR AERONAUTICS (concluded)				
COST OF FACILITIES	47.8	47.8		The advisory committee recommends favorable action on the cost of facilities budget.

Priority/Importance

90 - Extremely important
80 - Very important
70 - Important
60 - Worthy
50 - Borderline
40 - Just below entry level
30 - Minor
20 - Very minor
10 - Insignificant

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NASA AERONAUTICS BUDGET FOR FY87

CONGRESSIONAL AERONAUTICAL ADVISORY COMMITTEE ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE AND COMMENTS
AERONAUTICAL R&D (CONTRACTS)				
RESEARCH AND TECHNOLOGY BASE	272.9	274.4		
1. Fluid and Thermal Physics	39.5	39.5	79 (76-85)	We concur. The fundamental applied research and technology under this program will have a very important impact on aircraft designs of the future. NASA has the lead nationally and world wide on most of the research and technology contained under this program. The overall priority of this budget item is 79 and the individual programs range in priorities from 76 to 85. While computational fluid dynamics is extremely important, a great deal of funding is going into it under various budget categories, about $65M. Funding in this area has been vastly increased in the last five years. The advisory committee recommended last year that NASA hold budgetary increases for Computational Methods and Applications to within the rate of increase for NASA's aeronautics budget as a whole. The planned FY 87 NASA program for external ($5.9M here) and internal computational methods ($4.9M under item 3) total $10.8M, which falls within our recommendation of $11.3M for FY 86. Computational fluid dynamics is an extremely important research area for all kinds of aircraft. Impressive gains are being made in the capability to compute

Priority Importance

90 - Exceptionally Important
80 - Very Important
70 - Important
60 - Worthy
50 - Borderline
40 - Just below entry level
30 - Minor
20 - Very minor
10 - Insignificant

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NASA AERONAUTICS BUDGET FOR FY87

CONGRESSIONAL AERONAUTICAL ADVISORY COMMITTEE ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
1. (continued)				flow fields about aircraft to assist in the design of highly advanced aircraft. It is already possible to compute the flows for aircraft components and this year significant gains were made toward being able to conduct such computations for entire aircraft configurations. Correctly modeling the flow to obtain accurate answers remains a problem. Computational fluid dynamics will assist us in designing better aircraft configurations, but it will not reduce the need for wind tunnels to verify the results and test configurations that are difficult to model. NASA has essentially eliminated work in FY 87 in the program under Test Techniques on the magnetic balance and adaptive walls of wind tunnels. This amounted to $1.4M in the submitted FY 86 budget. The advisory committee recommended this adjustment last year. The wind tunnel modifications that would have been required to use these techniques would have cost over $100M; therefore, the committee considered this as a major item. The NASA submitted budget for Flow Modeling and Verification has been increased from $2.0M in FY 86 to $3.5M in FY 87 reflecting the increased emphasis we recommended to properly model flow fields. Successful use of computational fluid mechanics depends upon reliable, accurate mathematical models describing the flow about the aircraft. Reliability of the predictive models must be verified by experimental results before they can be used with confidence.

Priority Importance

90 - Extremely important
80 - Very important
70 - Important
60 - Worthy
50 - Borderline
40 - Just below worthy level
30 - Minor
20 - Very minor
10 - Insignificant

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NASA AERONAUTICS BUDGET FOR FY87

CONGRESSIONAL AERONAUTICAL ADVISORY COMMITTEE ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
1. (concluded)				Rapid gains in the field are being made which will make computational methods increasingly valuable in the future. With regard to Subsonic Laminar Flow Control, a subcommittee of the advisory committee conducted a special review this year of the laminar flow control efforts. Based on this review, our priority rating for this work is increased from 54 to 76 for subsonic applications and from 54 to 71 for supersonic applications. The limited subsonic Jet Star flight tests, while producing favorable technical results, still presents questions regarding practicality because of maintenance concerns and it did not address the hybrid design. Any further effort to address these issues should be based on an austere approach. To date, little has been done in addressing supersonic applications, but the availability of a high quality test facility and the potential payoff for supersonic cruise (SST) warrants work along these lines.

Priority / Importance

90 - Extremely important
80 - Very important
70 - Important
60 - Worthy
50 - Borderline
40 - Just below entry level
30 - Minor
20 - Very minor
10 - Insignificant

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NASA AERONAUTICS BUDGET FOR FY87

CONGRESSIONAL AERONAUTICAL ADVISORY COMMITTEE ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
2. Applied Aerodynamics R&T	57.1	57.8	79 (76-83)	Under this important budget category, aerodynamic theory and practice come together to provide design principles, guidelines, and data for a full range of aeronautical vehicles. The individual programs were given high priority ratings (76-83), and the funding levels were felt to be appropriate, except for the aeroacoustics area.
Aeroacoustics	1.2	1.8 (+0.6)	79	Because of a broad and growing need for fundamental work in aeroacoustics, it is recommended that funding be approximately doubled over the next two years, with an increase of $600K in FY 1987. University research programs might be an appropriate focal point for this work. There should be no change if it is not possible to add this small amount to the total aeronautics funding. • Future military and civil transports as well as helicopters will again be subject to severe aeroacoustics problems as they incorporate new technologies. • Prop Fans and unducted fans will present problems in meeting noise standards for transports. • Low noise is essential for the new generation of military and civil helicopters.

Priority/Importance

90 - Extremely important
80 - Very important
70 - Important
60 - Worthy
50 - Borderline
40 - Just below entry level
30 - Minor
20 - Very minor
10 - Insignificant

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NASA AERONAUTICS BUDGET FOR FY87

CONGRESSIONAL AERONAUTICAL ADVISORY COMMITTEE ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
2. (concluded)				• Future supersonic fighters will also encounter aeroacoustic problems in weapons bays and in regard to external noise effects on detection. • Supersonic transports cannot be considered without major efforts to control noise.

Priority Importance

90 - Extremely important 70 - Important 50 - Borderline 30 - Minor 10 - Insignificant
80 - Very important 60 - Worthy 40 - Just below worthy level 20 - Very minor

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NASA AERONAUTICS BUDGET FOR FY87

CONGRESSIONAL AERONAUTICAL ADVISORY COMMITTEE ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
3. Propulsion and Power R&T	35.7	35.7	75 (56-80)	We concur. NASA's propulsion R&T programs are very important to the nation. In the past, these programs have been extremely well coordinated with the military services and with industry. NASA has pursued needed avenues of propulsion R&T and provided the necessary catalyst to pull together all segments of the development and user industries to ensure technical relevancy and to obtain maximum leverage of their R&T dollars. The overall priority of this item is 75 and the individual programs range from 56 to 80 in priority. A planned increase of about 70 percent in stratified charge rotary engine R&T for small engine applications to $2.7M is consistent with our recommendation last year to increase efforts for general aviation. Internal computational fluid mechanics modeling of the entire propulsion system with appropriate experimental verification of the analytical codes. NASA's planned funding of $4.9M for this program falls within our overall recommendations last year regarding maintaining a reasonable funding level for computational fluid dynamics (see item 1). The submitted FY 87 NASA budget discontinues all efforts on the Altitude Wind Tunnel at Lewis following the advice last year of our advisory committee and others. The FY 86 submitted level of funding was $5M; with R&PM the total annual level would have been about $12M. The wind tunnel would have cost over $160M additionally.

Priority/Importance

90 – Extremely important
80 – Very important
70 – Important
60 – Worthy
50 – Borderline
40 – Just below entry level
30 – Minor
20 – Very minor
10 – Insignificant

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NASA AERONAUTICS BUDGET FOR FY87

CONGRESSIONAL AERONAUTICAL ADVISORY COMMITTEE ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
3. (concluded)				There is a concern among some members of our committee that moving the rotorcraft line item to Materials and Structures area might jeopardize future needed R&T efforts in roto-craft propulsion.

Priority / Importance

90 - Extremely important
80 - Very important
70 - Important
60 - Worthy
50 - Borderline
40 - Just below entry level
30 - Minor
20 - Very minor
10 - Insignificant

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NASA AERONAUTICS BUDGET FOR FY87

CONGRESSIONAL AERONAUTICAL ADVISORY COMMITTEE ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
Materials and Structures R&T	39.0	39.0	81 (67-87)	We strongly agree. NASA's structures program is being reshaped this year into a more highly productive and well balanced program. NASA basic work in Materials and Structures has played a major role in the advancement of aircraft of all types. Future needs will outstrip those of the past as greater demands are made for lower weight designs, more rugged airframes, greater strength at high temperatures, more resistance to damage and other needs. This item has an overall priority of 81 and individual programs range in priorities from 67 to 87. The NASA planned budget for FY 87 includes a new item for a broad basic program on rotorcraft structures, dynamics, and transmissions ($4.9M). This effort reflects a response to our advice last year to increase the effort on rotorcraft by $4.0M particularly for structures and dynamics prediction methods. NASA has stated to us that additional increases are planned for future years. The structural composites program has been increased in the planned NASA FY 87 budget from $4.13M to $8.7M. This program roughly reflects our FY 86 recommendations in direction and approximate magnitude of increased effort.

Priority / Importance

90 — Extremely important
80 — Very important
70 — Important
60 — Worthy
50 — Borderline
40 — Just below entry level
30 — Minor
20 — Very minor
10 — Insignificant

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NASA AERONAUTICS BUDGET FOR FY87

CONGRESSIONAL AERONAUTICAL ADVISORY COMMITTEE ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
5. Information Sciences R&T	26.8	26.8	74	This work is important, not only as a vital part of the Computational Fluid Dynamics effort, but also for other information processing developments necessary in aeronautics, e.g., software reliability of embedded software in flight systems. Included in this budget item is the cost of developing, operating and maintaining NASA's computing network, tying together the various computing resources within and between the NASA Centers.

Priority Importance

90 - Exceptionally important
80 - Very important
70 - Important
60 - Worthy
50 - Borderline
40 - Just below entry level
30 - Minor
20 - Very minor
10 - Insignificant

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NASA AERONAUTICS BUDGET FOR FY87

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BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
6. Controls and Guidance	24.5	25.5	72 (60-78)	The advisory committee feels that the controls and guidance activities described here are important. The programs range in priority from 60 to 78 and the overall priority is 72. We concur with the overall funding, except that increased emphasis is required on Handling Qualities and Control Theory in order to establish updated criteria for augmented aircraft operating at the extremes of the flight envelope. We recommend a $1.0M increase to the submitted FY 87 budget for this item. The change would restore the funding for handling qualities and control theory to the FY 86 level of $2.4M.
Handling Qualities and Control Theory	1.4	2.4 (+1.0)		

Priority Importance

90 - Extremely important
80 - Very important
70 - Important
60 - Worthy
50 - Borderline
40 - Just below worthy level
30 - Minor
20 - Very minor
10 - Insignificant

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NASA AERONAUTICS BUDGET FOR FY87

CONGRESSIONAL AERONAUTICAL ADVISORY COMMITTEE ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
7. Human Factors R&T	24.0	24.0	77	We concur with this proposed research effort which relates human performance to the aeronautical system. This includes terminal collision avoidance systems, human engineering, and crew interface with expert systems (advanced cockpits). These efforts are appropriate for NASA to undertake, and promote air traffic safety.

Priority Importance

90 - Extremely important
80 - Very important
70 - Important
60 - Worthy
50 - Borderline
40 - Not below worthy level
30 - Minor
20 - Very minor
10 - Insignificant

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BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
8. Flight Systems	21.5	21.5	74 (71-75)	We agree with this program. The overall priority in our opinion is 74 and individual programs range in priorities from 71 to 75. Work in this area supports coordinated wind tunnel, analytical and flight research investigations that are critical to aviation safety. The advisory committee endorses this effort because the activities lead to a better understanding of flight hazards, e.g. lightening, icing, heavy rain, and develop design criteria and operating techniques for safe operations for all types of aircraft. This program also supports analytical and experimental efforts aimed at developing the technology base for future fighter aircraft having short takeoff and vertical land capability and also fighters with greatly improved maneuverability at very high angles of attack.

Priority/Importance

90 – Extremely important
80 – Very important
70 – Important
60 – Worthy
50 – Borderline
40 – Just below entry level
30 – Minor
20 – Very minor
10 – Insignificant

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NASA AERONAUTICS BUDGET FOR FY87

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BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
9. Systems Analysis	4.8	4.8	74	We concur. NASA studies to evaluate and influence technology planning are valuable. We strongly support NASA's plan to conduct industry studies, under this budget, to evaluate the economic viability of an advanced U. S. supersonic transport.

Priority/importance

90 – Extremely important
80 – Very important
70 – Important
60 – Worthy
50 – Borderline
40 – Just below entry level
30 – Minor
20 – Very minor
10 – Insignificant

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NASA AERONAUTICS BUDGET FOR FY87

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BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
SYSTEMS TECHNOLOGY	103.1	103.1		
10. Rotorcraft Systems Technology	18.7	18.7	59 (76-57)	We concur with this program and related funding. The overall priority for this item of 59 was the result of the preponderance of funds allocated for technology for next generation rotorcraft (the X-wing/ RSRA Program) which was ranked 57. Advanced Rotorcraft Technology was ranked at 76.
Advanced Rotorcraft Technology	2.0	2.0	76	Under this item, NASA addresses only aeroacoustics. Helicopter noise is a high priority R&T area, very strongly endorsed by the FAA as well as industry. It is an essential element of the FAA's plan to enforce a helicopter noise rule. It is also an excellent example of a joint NASA/industry program in which industry has agreed to match NASA program with IR&D funds and exchange these IR&D results.
Rotorcraft Aeromechanics				Rotorcraft Aeromechanics work is transferred to another area of the budget for FY 87. In 1982, the committee reported its concern over a drastic reduction in rotorcraft basic systems technology efforts. We pointed out the critical importance of helicopter vibration work and recommended a $4M and a 5 manyear NASA manpower increment for rotorcraft vibration work. This recommendation was not implemented in FY 86. However, for FY 87 a $4.9M new line item is included by NASA for rotorcraft structures, dynamics, vibrations and transmissions work under Structures and Materials R&T (Item 4).

Priority/Importance

90 - Extremely Important
80 - Very Important
70 - Important
60 - Worthy
50 - Borderline
40 - Just below entry level
30 - Minor
20 - Very minor
10 - Insignificant

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BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
10. (concluded)				Considering all changes in the FY 87 budget relative to FY 86, the net increase in funding for rotorcraft work associated with vibrations is $3M. The planned FY 87 NASA manpower level was not provided to this committee this year so we do not know the result of our recommendation or a manpover increase.

Priority/Importance

90 – Extremely Important 70 – Important 50 – Borderline 30 – Minor 10 – Insignificant
90 – Very Important 60 – Worthy 40 – Just below worthy level -30 – Very minor

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BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
Technology for Next Generation Rotorcraft (X-wing)	16.7	16.7	57	The committee was seriously split on the merits of the program last year, but did reach a consensus on the priority this year. Our priority rating takes into account the following factors: • NASA's responsibility to the DoD to bring this program to fruition. • Doubts about the concept's final practicality as an operational aircraft because of its extreme complexity. • The fact that this demonstration program will not fully demonstrate the concept. The aircraft will not demonstrate hover like a helicopter or transition from hover to forward flight. This is basic to the final concept. • The fact that it will demonstrate conversion in forward flight from rotating to fixed blades and the operation as a fixed wing aircraft in forward flight. The committee strongly recommends re-evaluation of the concept's potential and future research needs after completion of the 40-hour flight test program.

Priority Importance

90 – Extremely important
80 – Very important
70 – Important
60 – Worthy
50 – Borderline
40 – Just below entry level
30 – Minor
20 – Very minor
10 – Insignificant

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NASA AERONAUTICS BUDGET FOR FY87

CONGRESSIONAL AERONAUTICAL ADVISORY COMMITTEE ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
11. High Performance Aircraft Systems Technology	26.0	26.0	77 (68-83)	We concur with the important work being conducted under this program. The programs vary in priority from 68-83 and the overall priority is 77.
High Performance Flight Research	10.4	10.4	80 (75-81)	This program conducts flight research using existing modified fighter aircraft and experimental aircraft to: explore the new technologies and design concept in the X-29, greatly expanded boundaries of maneuverability at high angles of attack using the F-18, investigate new wing design concepts with the AFTS-111 and F-106, conduct research on VSTOL aerodynamics and control with the Harrier and try highly integrated digital avionics with the F-15. The programs are valuable to advance basic generic technology of military fighters; a traditional NASA rule that has proved fruitful since the early days of the second World War.

Priority/Importance

90 – Extremely important 70 – Important 50 – Borderline 30 – Minor 10 – Insignificant
90 – Very important 60 – Worthy 40 – Just below entry level 20 – Very minor

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CONGRESSIONAL AERONAUTICAL ADVISORY COMMITTEE ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
11. (concluded) Turbine Engine Hot Section Technology (HOST)	5.0	5.0	83	The HOST program provides unique design tools to increase engine life. This is extremely important to both military and civil applications and will become even more so with the need for efficient supersonic cruise. The military is relying on this basic program to a great extent. About 50 percent of airline engine maintenance costs are related to the engine hot section, which results in about 25 percent of total airline maintenance cost. The committee recommended a $2.3M augmentation in FY 86 which was not enacted. HOST received an even higher priority rating this year than last year. NASA plans show efforts in this area being phased out even though there will be a need to advance technology in this area for all new engines. The advisory committee did not recommend an augmentation for this area for FY 87 because the tight budget situation and the soundness of the rest of the aeronautics budget precluded reasonable funds transfers from other areas.

Priority / Importance

90 – Extremely important
80 – Very important
70 – Important
60 – Worthy
50 – Borderline
40 – Just below worthy level
30 – Minor
20 – Very minor
10 – Insignificant

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NASA AERONAUTICS BUDGET FOR FY87

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BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
12. Subsonic Aircraft Systems Technology				This work was discontinued in FY 86 when the large composites program was cancelled by NASA. We recommended expansion of the basic composite structures program restoring $7.0M of these funds to this area for FY 86. NASA has included a $4M increase for FY 86 for the recommended basic composites structures work in the R&T base under item 4.

Priority/Importance

90 – Extremely Important
80 – Very Important
70 – Important
60 – Worthy
50 – Borderline
40 – Just below entry level
30 – Minor
20 – Very minor
10 – Insignificant

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NASA AERONAUTICS BUDGET FOR FY87

CONGRESSIONAL AERONAUTICAL ADVISORY COMMITTEE ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
13. Advanced Propulsion Systems Technology	28.4	28.4		We concur.
Advanced Turboprop Systems	26.0	26.0	84	We concur. This is an extremely important program. Prop Fan propulsion promises to provide major advances in transport efficiencies for both commercial and military applications. There are two concepts included in this program: (1) the Prop Fan and (2) the Unducted Fan. The primary Prop Fan program is a single row of blades and uses gears; the concept was to go into flight testing in FY 86. This has been the baseline NASA program since 1978 and has given rise to the entire class of new advanced propulsion systems and associated technologies. The competing concept in the program is the Unducted Fan which consists of counter rotating rows of blades without gears. The Unducted Fan will also go into flight testing in FY 86 and has the greatest commercial interest and funding. The baseline Prop Fan concept may find a greater application for aircraft modifications such as for naval patrol aircraft and for new general aviation aircraft. The Prop Fan is still a competitor to the Unducted Fan for future commercial transports, but not as great a competitor as it appeared last year. NASA has reduced the FY 87 funding level of the baseline Prop Fan program by about $15M which will

Priority/Importance

90 – Extremely Important
80 – Very Important
70 – Important
60 – Worthy
50 – Borderline
40 – Just below entry level
30 – Minor
20 – Very minor
10 – Insignificant

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NASA AERONAUTICS BUDGET FOR FY87

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13. (concluded)				impact the testing of cabin noise reduction methods and perhaps other aspects of the flight tests. NASA would also hold up all gear technology work, pending the outcome of the both flight tests.

Priority/Importance

90 – Extremely important
80 – Very important
70 – Important
60 – Worthy
50 – Borderline
40 – Just below entry level
30 – Minor
20 – Very minor
10 – Insignificant

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NASA AERONAUTICS BUDGET FOR FY87

CONGRESSIONAL AERONAUTICAL ADVISORY COMMITTEE ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
Ceramics for Turbine Engines	2.2	2.2	72	This is an important long term research into the fundamental material properties and manufacturing processes to establish the feasibility for use in aero propulsion and power. It is a difficult problem to develop ceramics tough enough for engine applications and to manufacture them accurately and unformally enough. However, there will be high payoff if this research is successful.

Priority/Importance

90 – Extremely Important
80 – Very Important
70 – Important
60 – Worthy
50 – Borderline
40 – Just below entry level
30 – Minor
20 – Very minor
10 – Insignificant

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BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
Oblique Wing Technology	8.4	8.4	68	We agree with this budget item. This effort supports the planned work for design of this oblique wing and its integration of the digital fly-by-wire aircraft. The priority given this item reflects a marked change from last year's low priority assessment of 38. We recommended last year that NASA restructure the program from a flight demonstration program to one of application studies and wind tunnel tests of pertinent configurations. While the committee still has reservations regarding this program. It now supports continuing the activity by virtue of the funding commitments already made to the Navy and the Navy's interest in the program. Flight demonstration of such a radical aerodynamic configuration would probably be a prerequisite to acceptance for any practical application. NASA's FY 86 funding for this item is $3.6M; a reduction of $1M from NASA's FY 86 submitted budget. The advisory committee had recommended a budget of $1.5M for FY 86. The advisory committee now agrees with NASA's FY 87 submitted budget.

Priority/Importance

90 – Extremely important
80 – Very important
70 – Important
60 – Worthy
50 – Borderline
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30 – Minor
20 – Very minor
10 – Insignificant

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NASA AERONAUTICS BUDGET FOR FY87

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BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
14. Numerical Aerodynamic Simulation	30	30	80	Our priority on this item has increased from 68 last year to 80 in recognition of the potential value of this work, evidenced by significant progress this year. The funding level represents about 8 percent of the aeronautical R&D contract budget and will be expended primarily for computers and the software to develop the simulation capability. Our change in priority was influenced by NASA's recent advances in computational fluid dynamics. The committee would again like to restate that the NAS will not eliminate the need to maintain NASA's wind tunnel capability.

Priority/Importance

90 – Extremely important
80 – Very important
70 – Important
60 – Worthy
50 – Borderline
40 – Just below entry level
30 – Minor
20 – Very minor
10 – Insignificant

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CONGRESSIONAL AERONAUTICAL ADVISORY COMMITTEE ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
CONSTRUCTION OF FACILITIES	47.8	47.8	8[illegible]	
Dryden Integrated Test Facility Construction	17.5	17.5	80	The propulsion, flight control, avionics and other elements of future aeronautical systems are becoming more integrated and interactive through common computer and software interfaces. This Integrated Test Facility provides the means to connect into the aircraft's internal control network to conduct ground qualification, comparability testing and validation of flight critical functions. It will lead to new testing and simulation capabilities and more efficient operations. The committee concurs with the need for this facility and supports the budget submitted.
Modification to Langley 8 Foot High Temp. Facility	9.7	9.7	80	This modification provides an expansion of test capability into the hypersonic (Mach 4 to 7 range) with proper altitude pressure and temperature conditions needed to support research applicable to missiles and the aerospace plane. The committee concurs with the budget submitted.
Addition to Langley Non-Destructive Evaluation Facilities	2.0	2.0	80	The need to develop new methods to perform non-destructive evaluation is essential to transition of new materials, structures, and manufacturing processes into aerospace industry products. Quality control, reliability and cost considerations are fundamental requirements that can be solved through these techniques. The facility supports this key research.

Priority/Importance

90 – Extremely important
80 – Very important
70 – Important
60 – Worthy
50 – Borderline
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30 – Minor
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NASA AERONAUTICS BUDGET FOR FY87

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BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
Repairs: Tunnels, Propulsion Facilities	8.1	8.1	80	We concur. It is essential to maintain and expand the productive test capability of existing NASA wind tunnels and propulsion facilities.
Rehabilitation and Modification: Wind Tunnels	8.9	8.9	80	We concur. It is very important to retain and expand the aerodynamic testing capacity of key national resources. Relatively modest investments in modification to existing wind tunnel can have a major influence on this nation's aeronautical systems design and development capability.
Minor Construction of Facilities	1.6	1.6	80	We concur. These modest allocations logically support the fundamental needs for maintenance, repair, rehabilitation and minor add-ons to existing facilities.

Priority/Importance

90 – Extremely Important
80 – Very Important
70 – Important
60 – Worthy
50 – Borderline
40 – Just below entry level
30 – Minor
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CONGRESSIONAL AERONAUTICAL ADVISORY COMMITTEE ASSESSMENT

BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
NATIONAL AEROSPACE PLANE	45	No comment	No comment	The committee strongly advises that any added research and development work in support of the National Aerospace Plane program should be justified in its own right and supported with a budget above and apart from the NASA aeronautics budget. • The Aerospace Plane is a highly specialized vehicle. The primary R&D required for it has little in common with research and technology advances vitally needed by the primary segments of aeronautics in: civil and military transports, naval patrol aircraft, fighters and attack aircraft, helicopters, general aviation aircraft, and related propulsion systems. • The Aerospace Plane would kill a large number of smaller important aeronautics R&T programs if this very large program is included in the NASA aeronautics budget without additional funds. The overall affect on aeronautical advances would be very serious. The National Aerospace Plane itself was not assessed by the Congressional Aeronautical Advisory Committee because: • Insufficient information is available to this committee on NASA's detailed plans in relationship to the DoD's research and development plans for

Priority/Importance

90 – Extremely important 70 – Important 50 – Borderline 30 – Minor 10 – Insignificant
80 – Very important 60 – Worthy 40 – Just below entry level 20 – Very minor

NASA AERONAUTICS BUDGET FOR FY87

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BUDGET ITEM	SUBMITTED BUDGET ESTIMATE ($ Millions)	RECOMMENDED ($ Millions)	PRIORITY ASSESSMENT	RECOMMENDATIONS, RATIONALE, AND COMMENTS
NATIONAL AEROSPACE PLANE (concluded)				the Trans-atmospheric Vehicle. • Much of the information needed to evaluate the joint NASA/DoD program in this area is classified and, therefore, unavailable to the entire advisory committee. • Almost all knowledgeable advisory committee members on this topic must disqualify themselves from the evaluation because their companies are bidding on the Air Force contracts for the Trans-atmospheric Vehicle, which may be impacted by the National Aerospace Plane program funding.

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